LONG-TERM FUTURE OF THE LANDSAT SYSTEM

HEARING

BEFORE THE

SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT

AND THE

SUBCOMMITTEE ON INTERNATIONAL SCIENTIFIC COOPERATION

OF THE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

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CONTENTS

WITNESSES

	Page
May 9, 1989:	
David S. Julyan, Executive Vice President, SPOT Image Corporation	10
Anatoly Shutko, Institute of Radio Engineering and Electronics, Academy of Sciences, U.S.S.R	33
Myron Laserson, Contitrade Services Corporation, Continental Grain Company, New York, New York	37
Tsuguo Tadakawa, National Space Development Agency of Japan, Director, Washington, D.C. Office; accompanied by Takuji Yamagami, Director, External Relations, NASDA, Tokyo, Japan	42
John McElroy, Dean, School of Engineering, University of Texas at Arlington, Arlington, Texas	87
Jerry B. Caseman, Harris Corporation, Alexandria, Virginia	106
Michael Meier, Vice President, KRS Remote Sensing, Landover, Maryland	123
Robert F. Brammer, The Analytic Science Corporation, Reading, Massachusetts	171
John J. Egan, President, The Egan Group, Inc	193

APPENDIX

Letter to Vice President Quayle, Chairman of the National Space Council, from Hon. Robert A. Roe, Chairman, and Hon. Robert S. Walker, Ranking Republican Member, Committee on Science, Space, and Technology	211
June 1, 1989 statement of the White House Press Secretary regarding the funding of the Landsat program	213

LONG-TERM FUTURE OF THE LANDSAT SYSTEM

TUESDAY, MAY 9, 1989

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT; AND SUBCOMMITTEE ON INTERNATIONAL SCIENTIFIC COOPERATION,
Washington, D. C.

The subcommittees met at 9:30 a.m. in room 2318, Rayburn House Office Building, the Honorable James H. Scheuer, chairman of the subcommittee, on Natural Resources, Agriculture Research and Environment, presiding.

Mr. SCHEUER. The Subcommittee on Natural Resources, Agriculture Research and Environment and the Subcommittee on International Scientific Cooperation will come to order.

This morning these two subcommittees will jointly return to the problem-plagued Landsat program.

In March, when we last tuned in on this saga, the National Oceanic and Atmospheric Administration was preparing to pull the plug on Landsat 4 and 5 for lack of funds. Of course, these are the two operational satellites which together constitute the United States civilian remote sensing system.

Now on the next Friday evening of the "Perils of Pauline," for those of you who are old enough to remember this great weekly show, as we dangled by our fingernails from the precipice, the National Space Council, led by Vice President Quayle, pulled off a last-minute reprieve and scraped together enough money to keep Landsat 4 and 5 flying until mid-July. Undoubtedly, there will be another Friday evening show as we dangle from the precipice in late June or early July anticipating what will happen to save the heroine on July 15th.

Now in the interim, the National Space Council launched a policy review to determine both the short-range and the long-term future of the Landsat system. This review comes at a very critical juncture in Landsat's history. The United States has had no policy for civilian remote sensing satellites in the last five years. It's been on again, off again, hit or miss, and it's been very painful for us who serve on this committee to see the United States falling behind other nations simply because we didn't have the will, we didn't have the commitment, we didn't have the determination to be first in this high-tech science area in which we by rights should be first.

This is the current issue of Life magazine and this is the finest satellite photograph of Washington that's ever been taken. You see

this little square where my finger is here. Well, this blows up to the Pentagon here. Now this should be the glory of the American space satellite remote sensing art, but it isn't. It's a Russian photo, five-meter definition. They've got an improved product that's well underway and here is a perfect example where the United States is perhaps third, behind SPOT, the French satellite system, behind the Russians, and perhaps behind the Japanese who are going to announce in the next year or two an extraordinarily sophisticated system.

And it's because we haven't gotten our act together. We haven't made determinations. We've been constantly involved in looking at the here and now and one-year funding and so forth, instead of looking down the road. We have constantly criticized our corporations for their predilection to look at the bottom line not only this year but this quarter. The security analysts have been inordinately preoccupied with short-term profits to the detriment of the American corporate capacity to look long term and to concentrate resources over a sustained period of time, which is absolutely necessary in order to be first.

So largely because of this preoccupation with the short term, we have been wiped out in consumer electronics by the Japanese; we've been almost mortally crippled in the automobile industry where now foreign cars have a 40 percent share of the market, over 50 percent in California. Here in high definition television, HDTV, it looks like a repetition of the same because we can't get our act together, define the problem, figure out who the leaders are going to be and then provide an adequate consortium of public-private financing.

Here again is another area where we're on the verge of losing the leadership because we can't seem to summon up the vision and the determination to do the job right, to figure out the challenge and the mission over the long term, and design the resources, design the funding, design the lead groups, and get on with the job.

This lack of commitment and lack of vision has plagued our attempts to commercialize the Landsat program. Almost since the ink was dry on the agreement between NOAA and EOSAT to develop a commercially viable Landsat system, NOAA has cut funding, threatened program shutdowns, and cut planned system improvements. And we are seeing the result of at least two and perhaps three foreign competitors being significantly and identifiably and provably ahead of ours with superior systems. While we have been floundering, the Soviets and the French have aggressively entered the commercial market to promote remote sensing data and our Landsat program is on the ropes.

Landsat 4 and 5 are struggling for funding as they operate well beyond their expected lifespan. This has been a superior achievement of our science and our technology. They are operating effectively and efficiently well beyond their expected lifetime and we're rewarding that success with almost total indifference and unconcern. Only one new Landsat is on the books. Landsat 6, a modestly improved version of Landsat 5, is scheduled for launch in 1991.

We urgently need a long-term, stable policy on a U.S. civilian remote sensing satellite system. We welcome the National Space Council's review and we commend with satisfaction and enthusi-

asm the Vice President of the United States, Dan Quayle, for his leadership and his courage on this issue. He has been about the only voice out there and it's sad.

This committee intends to be an active partner in forging a revitalized Landsat policy. This hearing this morning is the first of two hearings intended to provide a basis for our own policy development.

Today the subcommittees will consider the context in which any future U.S. Landsat system must be developed. We face a new era of international competition. Landsat and the Landsat technology is no longer a monopoly. The French and the Soviets have developed competing commercial systems and several other nations, including Japan, are well along in plans to develop and launch remote sensing satellites that could have vast commercial implications.

We are honored to have representatives of those countries with us today to help us discuss the U.S. role in this international market and the potential for international cooperation and burden-sharing, so to speak.

The potential for commercialization is a second factor. The market for remote sensing data is growing and many believe that we are on the verge of a true explosion in demand. But there is consensus among the analysts that we are years away from any self-sustaining commercial system like those that characterize the communications satellites.

Should the respective roles of government in this be changed or should we build on the government-industry partnership that has already been created? What are the implications of future market demand on the pace of commercialization and the development of advanced remote sensing technology?

A panel of contractors who have conducted market surveys for NOAA, the National Oceanic and Atmospheric Administration, will help us to address those questions.

And a third factor is national security. Landsat currently provides vital military and economic intelligence to the Defense Department and our national security agencies. How can these needs continue to be assured? We get it on very good authority that the Defense Department has expressed itself to this National Space Council they willy-nilly they are going to get this data that Landsat is producing and should continue to produce, and if there is any further faltering by our government on the civilian Landsat remote sensing program that the military will step in and do the job because they must continue to have their own needs filled.

To us, this would be a great tragedy because although we would by that development be fulfilling our military and security needs for remote sensing data, this information would for the most part be classified and it would not be available for the incredible length and array and breadth of use for our economy—almost every aspect of our economy, and for the 130 developing nations abroad that urgently depend on this information for information to them on what to plan, when to plant it, when to irrigate, when to fertilize, when to sow. It would be a great tragedy if the civilian sector of our economy and our government abandoned the remote sensing field to the military—a terribly tragedy, and would reflect very

poorly on the ability of the Congress and the executive branch to meet the civilian needs of our society.

Congressman Ron Packard of California, the Ranking Republican Member of the International Scientific Cooperation Subcommittee.

Mr. PACKARD. Thank you, Mr. Chairman. You have very succinctly described the problem I think that we struggle with. Certainly great uncertainty and volatility has been associated with our Landsat policy. It's already cost us dearly in world leadership and will continue to cause us a great deal of problems I think if it's not resolved soon.

You've already expressed that the continued operation of Landsat 4 and 5 have given us a few months of additional time to try to address and establish a national policy and certainly this is the time for Congress to take action and to recognize that we must enhance our competitiveness by addressing rather quickly and establishing a national policy regarding Landsat.

Certainly other countries are involved deeply and in many cases ahead of the United States in their experimental, operational and research systems—Canada, France, India, Japan, the USSR, and of course the European Space Agency. The government needs to follow through its initial agreement to promote and to support the program. The industry is at a volatile stage and still requires the government support originally foreseen when the contract was negotiated. It must be remembered that the importance of the Landsat program goes well beyond the commercial and economic value, as you've already stated. We need to look at the technological and scientific importance of Landsat in understanding the planet on which we live. We are spending billions of dollars on expeditions to our sister planets in this solar system but we continue to neglect our own back yard of planet Earth.

Landsat is a powerful and in some ways unique tool for the study of global change and the many large-scale environmental issues facing us now and in the future. These critical benefits must be considered as we determine a long- term policy for the Landsat program. We cannot forego the program's scientific and technological contribution simply because it cannot immediately make it on its own in our marketplaces.

In the development of a long-term policy, we must reexamine the mechanisms of first providing continuity into the future and also stimulating the market for such data. There are two mechanisms that certainly can be considered and perhaps others. One would be an international cooperative effort which we will be discussing in our hearing today, and another would be government and industry partnership here at home.

We look forward to exploring these and other options, Mr. Chairman, and I compliment you on calling the hearing and certainly look forward to hearing from our national as well as international friends on this issue.

Thank you, Mr. Chairman.

[The prepared opening statement of Mr. Packard follows:]

HONORABLE RON PACKARD (R-CA)
STATEMENT ON
HEARING ON THE FUTURE OF LANDSAT
MAY 9, 1989

THE GREAT UNCERTAINTY AND VOLATILITY ASSOCIATED WITH OUR NATIONAL LANDSAT POLICY HAS ALREADY COST US DEARLY IN TERMS OF WORLD LEADERSHIP IN LAND REMOTE SENSING, AND WE CAN EXPECT TO LOSE A GREAT DEAL MORE GROUND IF THE MATTER IS NOT RESOLVED SOON.

THE CONTINUED OPERATION OF LANDSATS 4 AND 5 HAVE AT MOST GIVEN US A FEW SHORT MONTHS TO REVIEW FUTURE PROSPECTS AND POLICY OPTIONS FOR A U.S. CIVILIAN REMOTE-SENSING SATELLITE PROGRAM.

AT A TIME WHEN CONGRESS IS FOCUSING ON ENHANCING OUR NATION'S COMPETITIVENESS, WE MUST RECOGNIZE THAT, REGARDLESS OF THE UNITED STATES' DECISIONS IN THIS AREA, THE RAPID

GROWTH OF INTERNATIONAL OPERATIONAL, EXPERIMENTAL, AND RESEARCH SYSTEMS IN CANADA, FRANCE, INDIA, JAPAN, THE U.S.S.R., AND ESA WILL CONTINUE.

THE GOVERNMENT NEEDS TO FOLLOW THROUGH ITS INITIAL AGREEMENT TO PROMOTE AND SUPPORT THE PROGRAM. THE INDUSTRY IS AT A VOLATILE STAGE AND STILL REQUIRES THE GOVERNMENT SUPPORT ORIGINALLY FORESEEN WHEN THE CONTRACT WAS NEGOTIATED.

IT MUST BE REMEMBERED THAT THE IMPORTANCE OF THE LANDSAT PROGRAM GOES WELL BEYOND ITS COMMERCIAL OR ECONOMIC VALUE.

WE NEED TO LOOK AT THE TECHNOLOGICAL AND SCIENTIFIC IMPORTANCE OF LANDSAT IN UNDERSTANDING THE PLANET ON WHICH WE LIVE. WE ARE SPENDING BILLIONS OF DOLLARS ON

EXPEDITIONS TO OUR SISTER PLANETS IN THIS SOLAR SYSTEM, BUT WE CONTINUE TO NEGLECT OUR OWN BACK YARD OF PLANET EARTH.

LANDSAT IS A POWERFUL AND, IN SOME WAYS, UNIQUE TOOL FOR THE STUDY OF GLOBAL CHANGE AND THE MANY LARGE SCALE ENVIRONMENTAL ISSUES FACING US NOW AND IN THE FUTURE.

THESE CRITICAL BENEFITS MUST BE CONSIDERED AS WE DETERMINE A LONG-TERM POLICY FOR THE LANDSAT PROGRAM.

WE CANNOT FOREGO THE PROGRAM'S SCIENTIFIC AND TECHNOLOGICAL CONTRIBUTIONS SIMPLY BECAUSE IT CANNOT IMMEDIATELY MAKE IT ON ITS OWN IN THE MARKETPLACE.

IN THE DEVELOPMENT OF A LONG-TERM POLICY, WE MUST RE-EXAMINE THE MECHANISMS OF

* PROVIDING CONTINUITY INTO THE FUTURE AND
* STIMULATING THE MARKET FOR SUCH DATA.

TWO SUCH MECHANISMS COULD BE INTERNATIONAL COOPERATIVE EFFORTS IN THE SPACE-BASED SYSTEMS AND A GOVERNMENT AND INDUSTRY PARTNERSHIP.

WE LOOK FORWARD TO EXPLORING THOSE OPTIONS TODAY.

THANK YOU.

Mr. SCHEUER. Thank you, Congressman Packard, for that really fine statement.

Congressman George Brown.

Mr. BROWN. No comment.

Mr. SCHEUER. Congressman Tim Valentine.

Mr. VALENTINE. Mr. Chairman, I don't have an opening statement except to thank the chairman for arranging this very interesting hearing.

Mr. SCHEUER. Thank you.

Congresswoman Claudine Schneider, who is the Ranking Republican Member on the Natural Resources, Agriculture Research and Environment Subcommittee, and who's been a very diligent and productive member of that subcommittee.

Ms. SCHNEIDER. Thank you very much, Mr. Chairman.

I think that I'd like to begin by congratulating you for holding this hearing and I think that clearly we recognize that a consensus has emerged that Landsat remote sensing is very much a vital system.

In previous hearings that we have held before this committee have given us ample documentation to support the value of Landsat data. Some of the users of that data include, as we know, government agencies, industry, researchers, and a whole series of other countries. And the information that monitors the status of the world's resources and used to explore for mineral deposits and even to support our own national defense cannot at all be undervalued.

However, there is also a consensus that has emerged that Landsat has received insufficient support. Some of the recent studies that we've looked indicate that Landsat will not be viable without some government support for many years to come. Yet from the beginning of this program the U.S. has been reluctant to commit the funds called for in the '84 commercialization act for Landsat satellites 4 through 7. Recently, there was even doubt that the administration would support funding of Landsat 4 and 5 through this fiscal year.

We hope that the Vice President's National Space Council which is reviewing this matter will find a way to keep these satellites flying.

I think that very clearly the solution requires a combination of two things. First, public, and also private cooperation. Right now the federal government needs to define what its role will be and commit itself to be a reliable partner until the program can be turned over to the private sector. Part of the government commitment to this program may be a joint effort between the U.S. and other countries with the capabilities in the remote sensing field, and I think that today's hearing will provide us with some of the overview of the various options that we might have in this area. So I hope all the supporters of remote sensing that are both in the private and public sector, as well as in this country and abroad, can take advantage of this opportunity to keep this very valuable system in operation for the future.

I think that it's about time that we rise above some of our individual interests so that we might serve a common purpose, and

clearly the purpose that we are looking at is one that will benefit all of humanity.

I thank you, Mr. Chairman.

Mr. SCHEUER. I thank my distinguished colleague and Ranking Minority Member.

We'll start with the first panel, the international satellite systems panel. We're going to be on the five- minute rule this morning, both congressmen here and members of the panel, because we have three panels and we have a significant congressional participation which indicates the degree of congressional interest and concern about this whole problem.

Congressman Paul Henry, we forgot to mention you, do you have an opening comment?

Mr. HENRY. No opening comments.

Mr. SCHEUER. Okay. So let us first recognize under the five-minute rule Mr. David Julyan, who represents the SPOT Image Corporation, the French system. May I say for all of you that your full prepared remarks as you have submitted them will be printed in their complete form at the point in the record in which you testify, so that you can be sure that the record will give the full statement that you have contributed.

Mr. Julyan.

STATEMENT OF DAVID S. JULYAN, EXECUTIVE VICE PRESIDENT, SPOT IMAGE CORPORATION.

Mr. JULYAN. Mr. Chairman and Members of the Committee, thank you for this opportunity to come before you today. This is the second time in the last two years that SPOT Image has participated in these committee deliberations and we appreciate that opportunity to be heard.

I would like to state at the beginning of my talk that I do not speak today on behalf of the French government, nor do I speak as a representative of the French space agency, CNES. I am here today as a representative of SPOT Image, the worldwide exclusive distributor of all the data collected by the SPOT satellites. SPOT Image is the commercial entity that is the part of the SPOT program that is responsible for development of the markets and servicing our customers.

I'd like to briefly summarize the statement that I've submitted for the committee and perhaps through that highlight some of the areas that we might focus on this morning.

We are on the ground floor of an industry with a tremendous future for reshaping the way we receive vital information about our planet. How significant will the impact of this new technology be? That's still to be determined. But a leading expert in this area has noted that "The impact of commercial satellite remote sensing systems is potentially great and may eventually rival that of television and other recent forms of information technology".

Our progress and success thus far have been based on the high quality of data products now being produced, the commitment of the employees within the industry, and the growing acceptance by our clients of the products, services and benefits available from our industry.

SPOT has demonstrated that the reliable delivery of high quality satellite data provides a foundation for commercial success. Users operational information requirements are now being met with efficient and economic remote sensing solutions. A full description of the SPOT satellite system data acquisition capabilities and characteristics, a chronology of SPOT's evolution, and existing and potential applications have been included as a part of my statement.

Our first three years of operation have been both exciting and profitable. We find ourselves as a service- oriented business and dedicated to providing SPOT data as a reliable, useful and economical information tool. The evolution of SPOT Image Corporation has been driven by the flexibility we have maintained in relation to understanding the needs of the marketplace, particularly new users, and tailoring our products and services to meet those needs. This has taken us from being a primary data supplier to working with value-added firms to produce special products and solutions.

Today we are a supplier of information and products designed specifically to meet the commercial operational needs of the new and existing users.

From SPOT's beginning, this has been the role of the commercial entity within the SPOT system. We have always and we will continue to maintain a clear and well-defined division of responsibilities between the government and the private sector's involvement in our system.

Early in the program it was recognized that government coordination and resources were necessary to launch the program and the satellite. At the same time, it was recognized that the commercial policies and operations required to achieve success needed to be established and managed by a separate and distinct private company—not a public agency.

SPOT Image was created specifically to fulfill this latter function. Our organization will continue to operate strictly as a commercial business providing products and services under the well-known principles of Open Sky and Open Access.

SPOT's commercial activities have resulted in significant industry growth and development. In 1988 SPOT worldwide revenues exceeded $17 million, which is an increase of over 60 percent from 1987 revenues. In the U.S. market, this annual percentage increase was even greater. Our initial estimate was that the U.S. would contribute 30 to 40 percent of SPOT's worldwide sales and we are on target with that estimate.

The growing commercial acceptance of our industry in the U.S. is further evidenced by the following figures. Between 1987 and 1988, the percentage of SPOT revenues from new, private sector applications in the United States grew from 35 percent to 65 percent of our total. This trend continues in our new 1989 business development and we anticipate an even higher percentage this year.

Growing private sector involvement and confidence is apparent in other areas as well. The major private sector SPOT shareholders recently doubled their equity position from 17 percent to 35 percent of the SPOT Image ownership. This is now equal to the equity position of CNES, the French space agency, which is the official owner and operator of the SPOT satellite and previously the major shareholder of SPOT Image.

The future viability of our industry rests on continuing to identify new commercial users of our technology and, most important, on those same users determining the actual value they place on our deliverables. The value established by the marketplace must generate sufficient revenue to cover acquisition and delivery costs if our industry is to maintain its commercial status.

The SPOT system was designed from the beginning with long-term system and industry development in mind. SPOT's vision and plan for the future is in place and on track with the flexibility to react to developments within the industry.

We currently have nine operational ground receiving stations with several more scheduled to open in the near future. The SPOT 2 satellite will be launched during the last quarter of this year. SPOT 3 is currently under construction. SPOT 4 and additional satellites are well along on their scheduled decision making process.

I would like to emphasize that there will be additional satellites coming from the SPOT program beyond SPOT 3 and SPOT 4.

One last brief comment if I might, Mr. Chairman, regarding alternative scenarios for the future. SPOT's long-term plans and commitment to the future are well- established. At the same time, various proposals for international cooperation, such as the proposed NOAA-CNES joint venture, are interesting and attractive scenarios for the future. While it is obvious that SPOT commercial policies and practices would easily fit into such a cooperative venture, it is very important to emphasize the following.

SPOT's aggressive commercialization efforts and activities will continue without change until such a scenario becomes a reality. The proposed cooperation would positively enhance both the commercial development of SPOT and the joint venture itself.

On the other hand, if the joint venture does not materialize, SPOT would continue to capitalize on its own success. Implementation of the proposed NOAA-CNES venture is not necessary to the success of SPOT nor the success of commercialized remote sensing.

Mr. Chairman, I will submit the rest of my statement for the record and thank you very much.

[The prepared statement of Mr. Julyan follows.]

STATEMENT PREPARED FOR

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

SUBCOMMITTEES ON:

INTERNATIONAL SCIENTIFIC COOPERATION

AND

NATURAL RESOURCES, AGRICULTURE RESEARCH AND ENVIRONMENT

PRESENTED BY DAVID S. JULYAN
EXECUTIVE VICE PRESIDENT
SPOT IMAGE CORPORATION

MAY 9, 1989

SPOT Image Corporation 1897 Preston White Drive • Reston, VA 22091-4368 • (703) 620-2200 • Telex 4993073 • Telecopier (703) 648-1813

INTRODUCTION

We are in on the ground floor of an industry with tremendous future for reshaping the way we receive vital information about our planet. How significant will the impact of this new technology be? An article in the Bulletin of Atomic Scientists, stated it well. "The ... impact of commercial satellite remote sensing systems is potentially great and may eventually rival that of television and other recent forms of information technology."

The issues and problems associated with developing this new industry are well known to this committee and others here today. We have come this far because of the widely recognized potential and value of this technology and the understanding that to maximize the benefits for the entire world, we must traverse the early stages of commercialization. Our progress and success thus far have resulted from the high quality of the data products now being produced, the commitment of the employees within the industry and the growing acceptance by our clients of the products, services and benefits available from the technology.

The launch of the SPOT 1 satellite three years ago marked the operational beginning of "commercialized" remote sensing and the transition from a primarily government supported R&D program to a commercially based, market driven industry. SPOT has demonstrated that the reliable delivery of high quality satellite data provides a foundation for commercial success. Users' "operational" information requirements are now being met with efficient and economical remote sensing solutions. Now that this initial stage has been successfully completed, the remote sensing industry is prepared to move on to the next "phase" of our business; working with our customers to establish the value of remote sensing solutions and delivering those solutions in a commercially acceptable and reliable manner.

A description of the SPOT satellite system, data acquisition capabilities and characteristics, a chronology of SPOT's evolution, and existing and potential applications are contained in the appendix at the end of this document.

INITIAL COMMERCIALIZATION

SPOT's first three years have been exciting and profitable. Our initial assumption that the foundation for a financially successful industry demanded a commercial source for satellite data has been proven both by our sales revenue and by the increasing number of new users turning to SPOT. We showed that when satellite data are of high technical quality and delivery is on a reliable and commercial basis, users will have confidence in relying on our industry as a valuable source of information.

SPOT is a service oriented business. We are dedicated to providing SPOT Data as a reliable, useful and economical information tool. We have worked closely with our customers, both previous users of satellite data and new clients, in establishing the business of data supplier and solution provider. We are confident that a sound commercial foundation has been established, but even more important is our customers' increasing acceptance of and confidence in our industry.

The Remote Sensing Industry is taking on its commercial definition. The identity and role of the major firms shaping the industry is now known. Leading "value added" service and system companies have responded to the commercialized environment by aggressively pursuing new opportunities which emphasize the use of remote sensing as an operational information tool rather than simply an R&D project opportunity. SPOT has worked closely with many of these value added firms to determine how best to identify and meet our customers' requirements and how to market our industry. Traditional economic and business criteria are now being used to define products and services to our customers. These customers are responding with a rapidly increasing interest in and reliance on our deliverables.

The evolution of SPOT Image Corporation has been driven by the flexibility we have maintained in relation to understanding the needs of the marketplace, particularly new users, and tailoring our products and services to meet those needs. This has taken us from being a primary data supplier to working with value-added firms to produce special products and solutions. Today we are a supplier of information and products designed specifically to meet the commercial operational needs of the new and existing users.

From SPOT's very beginning, this has been the role of the commercial entities within the SPOT system. We have always and will continue to maintain a clear and well-defined division of responsibilities between government and private sector involvement in our system. Early in the program it was recognized that government coordination and resources were necessary to launch the program and the satellite. At the same time, it was recognized that the commercial policies and operations required to achieve success needed to be established and managed by a separate and distinct private company, not a public agency. SPOT Image was created specifically to fulfill this latter function. Our organization will continue to operate strictly as a commercial business providing products and services under the well-known principles of open skies/open access.

THE INDUSTRY TODAY

A necessary part of the transition from what remote sensing was to what it will be are changes in product definitions and pricing structures. During the Landsat era, satellite data were provided from the perspective of government support to R&D studies. This

dictated one set of product and pricing policies. The value of the data in particular situations, especially commercial applications, had not been established. The costs associated with acquiring and delivering the data were not subject to the business reality of a profit and loss statement. The primary objective of these programs was to get data into the hands of researchers to determine interest and applicability.

Today we have gone well beyond this stage. While we provide data to the established users who have the capability to work with those data, the emerging commercial markets are not interested in buying data and becoming experts in remote sensing. These new markets are buying information and specialized products which fit directly into their operational activities.

Information needs of multiple clients and markets are being identified and standardized. Those needs are now being met with "commodity" products which can be produced in high volume for low cost, and widely distributed. Other "specialty" products are being produced for more specific applications and clients. The production of these derived "information products" which can be readily integrated into business decision making are an indication of the trends and increasing commercial maturity of our industry.

SPOT's commercial activities have resulted in significant industry growth and development. In 1988 SPOT worldwide revenues exceeded $17 million which is an increase of over 60% from 1987 revenues. In the U.S. market, this annual percentage increase was even greater. Our initial estimate was that the U.S. would contribute 30% to 40% of SPOT worldwide sales and we are on target with that estimate. As a means of comparison, sales growth for the Fortune 500 companies increased an average of only 7.6% during 1988.

The growing commercial acceptance of our industry in the U.S. is further evident in the following figures. Between 1987 and 1988, the percentage of SPOT revenues from new private sector applications, as opposed to government use, increased from 35% to 65% of the total.

This trend continues in our new 1989 business development and we anticipate an even higher percentage this year. Growing private sector involvement and confidence is apparent in other areas also. The major private sector SPOT shareholders recently doubled their equity position from 17% to 35% of the total investment in SPOT Image's commercial operation. This is now equal to the equity position of CNES, the French space agency which is officially the owner/operator of the SPOT satellite, and previously the major shareholder in SPOT Image.

SPOT's primary purpose remains the reliable delivery of high quality SPOT Data products and services. We have already committed the necessary financial and business resources to ensure continuity of SPOT Data to our customers. Our global

organization of receiving stations, processing centers and commercial distribution outlets is now meeting our customers' requirements on a daily and routine basis.

In addition, we have a responsibility to identify and open new markets for the use of our data and related products and services. To this end, we now also offer our customers the necessary management services which are required to transform data into information.

The development of new markets relies on continuing to find ways to provide information as opposed to data. This involves working with our customers to design and deliver cost effective remote sensing solutions to meet their information requirements. An essential part of this approach includes drawing upon the entire range of capabilities within the industry, particularly those offered by value added firms. The key is in providing our customers with efficient and economical solutions to their problems without them having to master the technologies of remote sensing or to select and coordinate various subcontractors.

The future viability of our industry rests on continuing to identify new commercial users of our technology and, most importantly, on those same users determining the actual value they place on our deliverables. The value established by the marketplace must generate sufficient revenue to cover acquisition and delivery costs if our industry is to maintain its commercial status.

The costs which must be recovered are not limited to SPOT. They include the value added service firms which actually extract customer requested information from SPOT Data, and the image processing equipment manufacturers whose systems are the tools of our trade. We must all work together, recognize our inter-dependencies and share the investments necessary for developing our markets. The experiences of the past clearly show that there is an identifiable value for our deliverable products and services which will not only cover costs, but ensure profits. We are confident that the development of the industry is on track for providing the necessary return on investment which is fundamental to a successful commercial venture. We recognize that it will be necessary for investments to continue, but we are equally confident that remote sensing is a sound investment and a unique and exciting business opportunity.

THE FUTURE

The SPOT system was designed from the beginning with long term system and industry development in mind. SPOT's vision and plan for the future is in place and on track with a flexibility to react to developments within the industry. SPOT's plans for the future include both commercial and technological evolution. Commercially our mandate is to continue to develop new markets for our information products and to develop new products and services to supply those markets. We are involved directly with

helping to develop new applications image processing and information extraction techniques within the value added sector of our industry specifically to meet these needs.

We currently have nine operational ground receiving stations with several more scheduled to open in the near future. The SPOT 2 satellite will be launched during the last quarter of 1989 and SPOT 3 is currently under construction. These first three satellites are identical in their image acquisition capabilities.

SPOT 4, scheduled for launch in the mid-1990s, will contain a number of specific innovations designed to meet anticipated future needs within the user community. The 10 and 20 meter resolution data produced by SPOT 4 will be co-registered onboard the satellite instead of on the ground during image processing. This is in response to the increasing needs of the cartographic user community which requires higher levels of accuracy for their increasingly sophisticated applications. A middle infrared band will also be added to our standard sensors for improved capabilities in vegetation study.

It is currently planned that SPOT 4 will carry an additional, self-contained sensor tentatively called "Vegetation", designed to improve the monitoring capabilities of the world's vegetation and oceans. This new sensor will provide daily coverage of the Earth's surface and will record images in five separate spectral bands: blue, green, red, near infrared and middle infrared. It will also have increased radiometric sensitivity, allowing it to detect slight variations in Earth surface characteristics over space and time.

The launch schedule and sensor configurations for SPOT satellites beyond SPOT 4 will be determined by the needs of our customers and other developments within our industry.

Alternative Scenarios for the Future

SPOT's long term plans and commitment to the future are well established. At the same time, various proposals for international cooperation, such as the proposed NOAA/CNES joint venture, are interesting and attractive scenarios for the future. While it is obvious that SPOT commercial policies and practices would easily fit such a cooperative venture, it is very important to emphasize the following: SPOT's aggressive commercialization efforts and activities will continue without change until such a scenario becomes reality. The proposed cooperation would positively enhance both the commercial development of SPOT, and the joint venture itself. On the other hand, if the joint venture does not materialize, SPOT would continue capitalizing on its own success.

Implementation of the proposed NOAA/CNES venture is not necessary to the success of SPOT nor the success of commercialized remote sensing. It is one of several concepts generated as a result of confidence in the industry's future based on the positive

commercial trends and market growth seen today. It is an attractive alternative because it allows for the proper definition of government and private sector roles which will bring about commercial success and technological growth. It will also allow the U.S. and French governments to reduce their costs in achieving their goals in satellite remote sensing.

SPOT's customers are speaking with a clear and positive voice about the value they place on SPOT based information solutions to their commercial requirements. Concurrently, as a private business operation, we are aware of the costs associated with meeting these requirements. We remain fully convinced that ongoing market development will eventually generate sufficient revenues to cover the major expenses of all segments of the SPOT program.

CONCLUSION

The SPOT program is proving that remote sensing technology has evolved to the point where it can function successfully in a commercial environment. Satellite based remote sensing technology has progressed through a series of government research and development programs over the last 15 years. SPOT has taken this technology, geared it toward commercial applications, and improved the technology to meet commercial needs. In doing so, SPOT has relied on three key concepts: 1) government and private sector can work together to establish and achieve commercial goals; 2) traditional business concepts and technical considerations can be applied simultaneously to achieve goals in each realm, and in fact, can serve to enhance one another; and 3) aggressive marketing of the technology can be a tremendous benefit to society in that the utility of the technology can be demonstrated to people around the world who will then find ways to use it to improve business practices, as well as government and academic studies.

APPENDIX

SPOT CHECK

SPOT Satellite System Facts

Products Offered by SPOT Image Corporation

SPOT IMAGE CORPORATION CHRONOLOGY

REMOTE SENSING AND THE SPOT PROGRAM

REMOTE SENSING APPLICATIONS: NEW POTENTIAL FROM SPOT

SPOT IMAGE CORPORATION COMMERCIAL POLICY STATEMENT

SPOT CHECK
SPOT 1 Satellite System Facts

SPOT: Satellite Pour l'Observation de la Terre (Earth Observation Satellite)

- Launched on February 21, 1986, 8:44 p.m. (EST) from Kourou, French Guiana

- SPOT 1 dimensions
  Body - 2m x 2m x 4.7m
  Solar Panels - 15.6m
  Weight - 1806kg

- Orbit
  Sunsynchronous, near-polar
  Altitude - 832km
  Inclination - 98.7 degrees
  Orbital cycle - 26 days for complete Earth coverage
  Equatorial crossing - 10:30 AM mean local solar time

- Sensors
  Two high resolution visible (HRV) instruments
  Adjustable view angle - 27 degree range east and west of the orbital path
  Ground imaging swath - 60km/instrument, 117km (3km overlap) when combined (vertical viewing)

- Spectral resolution (wavelength bands)
  Panchromatic - .50 to .73 microns
  Multispectral - .50 to .59 microns (green band)
  .61 to .68 microns (red band)
  .79 to .89 microns (near infrared band)

- Ground resolution (pixel size)
  Panchromatic 10m x 10m
  Multispectral 20m x 20m

SPOT Image Corporation *1897 Preston White Drive · Reston, VA 22091-4326 · (703) 620-2200 · Telex 4993073 · Telecopier (703) 648-1813*

Data Items offered by SPOT Image Corporation

- Satellite images available as:
  Computer-compatible tapes (CCT)
  Photographic prints
  Transparencies

- Standard single scene size:
  60km x 60km (vertical view angle)
  60km x 80km (maximum view angle: 27°)

- Scenes available at the following scales:
  1:100,000 1:250,000 1:400,000

- Processing levels for data items:
  Level 1A - raw image data with radiometric corrections to normalize detector response

  Level 1B - radiometric corrections and geometric corrections for viewing angle, systematic and orbital effects

  Level 2 - radiometric and geometric corrections - image presented at a specified cartographic projection

  Level S - radiometric and geometric corrections - multidate scenes registered to one another

A SPOT IMAGE CORPORATION CHRONOLOGY

1977	SPOT remote sensing program initiated by French government in cooperation with Belgium and Sweden.
July 1982	SPOT IMAGE S.A., responsible for worldwide marketing of SPOT Data, formed in Toulouse, France.
December 1982	SPOT Image Corporation formed to market SPOT Data exclusively to the U.S. remote sensing user community.
January 1983	SPOT Image Corporation headquarters opens in Washington, D.C.
February 1983	SPOT Simulation Campaign announced in the U.S. Simulated SPOT Data, acquired by airborne sensors, distributed to researchers to introduce user community to the SPOT program and SPOT Image Corporation.
May 20-23, 1984	SPOT Symposium held in Scottsdale, Arizona. Results of SPOT Simulation Campaign research projects are released.
August 1985	SPOT Image Corporation moves to new corporate headquarters and processing facility in Reston, Virginia.
February 21, 1986	Launch of SPOT 1, the first SPOT satellite, from Kourou, French Guiana on an Ariane 1 rocket. Initial in-orbit testing period begins.
May 1, 1986	SPOT 1 acquires imagery of Chernobyl Nuclear Power Plant in the Soviet Union following nuclear accident. These images, otherwise unobtainable, were used throughout the world by the news media to cover the event. The general public is introduced to SPOT and to one of the many benefits of remote sensing.
May 6, 1986	Initial in-orbit testing of SPOT 1 is successfully completed; SPOT Image Corporation officially begins commercial operation.
July 24, 1986	SPOT Image Corporation signs agreement with Canadian Center for Remote Sensing (CCRS) to receive SPOT satellite imagery of the U.S. directly from the two Canadian SPOT receiving stations.
August 22, 1986	SPOT Image Corporation signs agreement with NOAA to supply image data to the United States National Satellite Land Remote Sensing Data Archive.
October 13, 1986	SPOT Image Corporation becomes a fully operational data distribution and processing center with in-house capability to produce SPOT Data items from raw data tapes.
Mid 1988	Global network of 13 SPOT receiving stations scheduled to be fully operational. Additional station locations are under consideration.
1989 & Beyond	Planned launches of follow-on SPOT satellites to ensure image availability into the 21st century.

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REMOTE SENSING AND THE SPOT PROGRAM

Orbiting high above the Earth, satellites can take "pictures" of any area on our planet's surface. From this remote perspective, these images reveal far more than regular photographs. This "eye in the sky" provides us with detailed information, the uses of which are becoming more common and valuable as the technology continues to evolve.

Every surface on the Earth receives solar radiation which is either reflected, or absorbed and emitted in specific wavelengths, some of which are invisible to the human eye. A surface's characteristic "spectral signature" is made up of these specific wavelengths which can be recorded by special satellite-mounted "cameras," called sensors. The recorded spectral signatures are subsequently processed into photograph-like images.

The images are composed of thousands of individual picture elements, called pixels, each one containing a single unit of information which represents the spectral signature of the corresponding area on the Earth's surface. The ground area covered by each pixel determines the resolution, generally equivalent to the dimensions of the smallest detectable object on the image. The information content of the pixels is in digital form so that it can be analyzed by computer or converted to photographs for visual analysis.

From space, these remote sensing satellites provide images of large areas on the Earth's surface. Images can be acquired of any location, including those which are otherwise inaccessible for any reason.

The value of remote sensing has always been recognized in a wide variety of environmental disciplines, particularly those involving planning, management and development of man-made and natural resources. Disciplines for which remote sensing has traditionally played a valuable and sometimes indispensable role are geology, hydrology, forestry, agriculture, cartography and land use/urban planning. A typical application involves using imagery as a cost effective tool for analyzing large areas, or for screening those areas to identify smaller sections requiring more detailed study with aerial photographs, field studies or other methods of investigation.

Recent developments in remote sensing have been introduced by the SPOT system, resulting in imagery which is much improved over that previously available. The new imagery can now be used to perform increasingly detailed studies and consequently has inspired many new applications. With clarity and detail approaching that of aerial photographs, the news media now uses SPOT satellite pictures for visual support and, with analytical interpretation, as an actual news source. Similarly, the improved quality and detail of the latest imagery permits its use in real estate information systems for siting studies and other analyses within densely developed urban and suburban environments.

Satellite-based Remote Sensing
The First Generation

The U.S. government began a remote sensing research and development program in 1952 with the launch of the satellites TIROS and NIMBUS, both with resolutions of about 1000 meters. When the U.S. Landsat program began in 1972, resolution was sharpened to 80 meters and then, with the latest in the Landsat series, 30 meters. Through this technological evolution, the international user community, which had been using imagery from the U.S. government's satellite program, began to realize tremendous value in this data source. It was recognized as particularly useful in oil and gas exploration and in crop assessment and forecasting. As resolution improved and the users developed more sophisticated methods of data analysis, increasing numbers and types of applications were realized. For many disciplines, remote sensing became an indispensable tool. The growing demand for this data source began to exceed the existing, non-commercial system's ability to meet that need.

SPOT:
The New Generation of Remote Sensing

A new generation of remote sensing began with the launch of the SPOT 1 satellite on February 21, 1986. The SPOT program is unique in its technological capabilities. It also represents the transition of remote sensing from a government sponsored research and development program to a commercially viable operation.

The state-of-the-art SPOT satellite offers high resolution images which bridge the gap between the detail of aerial photography and the coverage and analytical power of satellite imagery. Panchromatic (black and white) images have a ground resolution of 10 meters which is nine times more detailed than images available from other civilian satellites. Three-band multispectral (color) images have a ground resolution of 20 meters and a spectral resolution which provides important information about vegetation, water bodies, urban areas and other forms of land cover.

Of particular significance on the SPOT satellite are the twin high resolution visible (HRV) sensors. The ad-

vanced solid state technology of these instruments produces image quality and detail never before available from civilian satellites. Each sensor's "look direction" is controlled with a pointable mirror allowing image acquisition over a range of angles up to 27 degrees from vertical. Looking sideways, the satellite can acquire images of a given location with much greater frequency than other satellites - up to 12 times during SPOT's 26 day orbital cycle. This capability is useful for monitoring rapidly changing processes and events on Earth and for increasing the possibility of image acquisition over areas with frequent cloud cover. The adjustable viewing angle also allows for the production of "stereopairs" of images for 3-dimensional viewing, a technique of particular value in terrain analysis, mapping and geological studies.

In addition to the advanced technical capabilities of the SPOT satellite, the commercial nature of the entire program offers tremendous advantages to the user community. First and foremost it ensures that SPOT Image Corporation is service-oriented, providing high quality data to users in an efficient, timely manner. Commercial success depends on a continually growing market of users. To allow existing users to confidently develop long-term application programs and to inspire the exploration of new applications, the SPOT series consists of three more satellites to be launched consecutively, ensuring a continuous supply of data into the next century.

The Remote Sensing Industry

The remote sensing industry consists of three main components: the suppliers of data, e.g., SPOT Image Corporation, the manufacturers of computerized image processing systems and the value-added companies.

As a leader in this newly commercialized industry,SPOT is closely tied to the developments occurring within all segments.

The value of remote sensing is increasingly realized through the use of digital image data with computerized information and image processing systems. Recent advances in these systems have freed the digital data user from the need for expensive, highly technical mainframe computer systems. Image processing and various geographic information systems (GIS) are now available on microprocessors and personal computers, with user friendly and application specific software. This has helped make remote sensing technology much more accessible, affordable and valuable to both first-time and experienced users.

The value-added companies, which often serve as consultants to end users, provide related services such as image processing and interpretation. Their role and value in the industry, and to the end user, have increased with the introduction of SPOT. At the same time, as the end users increasingly acquire and operate their own systems, the value-added companies are increasing their capabilities and developing more diversified applications and services for their clients.

This is an exciting and important time for remote sensing as the introduction of SPOT has created momentum for further development throughout the industry. The resultant changes are inspiring the exploration and development of new applications by end users. This trend, in turn, is inspiring suppliers, system manufacturers and value-added companies to develop new products and to improve their services to the end user community. SPOT Image Corporation is playing a leading role in this process, and is ensuring the success of the company and the industry as a whole by providing data which is more powerful and accessible than ever before. ■

REMOTE SENSING APPLICATIONS: NEW POTENTIAL FROM SPOT

The value of remote sensing for many environmental disciplines is well known. Significant savings of both time and money have been realized by using satellite imagery to limit the need for more costly data gathering methods such as field work or aerial photo interpretation. The efficiency and the value of this unique data source are so significant, in fact, that many federal and state agencies, private companies and individuals regard it as an indispensable tool. In leading the transition of remote sensing from research and development to commercial operation, SPOT has made the technology more valuable, accessible and essential than ever before.

The state-of-the-art capabilities of the SPOT system are providing increased value to existing applications and inspiring the development of many new applications. These capabilities include: 10 meter ground resolution, which is nine times more detailed than the resolution available from any other civilian satellite; the ability to acquire images of the same location several times each week as opposed to twice a month as with other satellites; and the ability to produce 3-dimensional stereoscopic images. In addition, SPOT's commercial, service-oriented organization ensures that it will be responsive to the needs of the user community. This includes the range of data products available - from photographs and transparencies for visual presentation and manual interpretation to digital tapes for more sophisticated analysis with computerized information systems.

The following sections describe some of the traditional and newly developing applications for satellite- based remote sensing, areas in which SPOT is rapidly establishing itself as a powerful new tool with tremendous potential.

GEOLOGY

Exploration geologists and oil companies frequently use remote sensing as an effective way to survey large land areas and identify surface indicators of potentially valuable subsurface mineral and oil deposits. By using this technology to identify and map such indicators as vegetation anomalies and certain geomorphic conditions, these companies can plan for the most efficient use of more expensive ground-based exploration techniques.

Remote sensing is commonly used in geologic mapping for engineering purposes such as road siting and construction, or dam siting within large drainage basins. Imagery is also used to identify and map large scale geologic features such as faults, fractures and fold systems. These features are often not apparent with the small area coverage provided by aerial photographs, though they are essential to analyzing overall geologic structure.

These capabilities also provide a powerful tool for monitoring short term geologic hazards such as landslides, volcanoes and earthquakes. SPOT 1's rapid revisit capability allows frequent image acquisition for observing these rapidly changing processes. For any geologic application which involves mapping terrain relief, SPOT's ability to produce stereoscopic image pairs with high spatial resolution will greatly increase the value of remote sensing as an essential tool for this discipline.

WATER RESOURCE STUDIES

Previous satellites have provided useful data for water resource studies, though ground resolutions were insufficient to define many of the typical features of water bodies and wetland areas. This is especially true in the National Wetlands Inventory program in which wetland maps for the entire U.S. are being prepared. SPOT offers the high resolution, spectral bands, and location accuracy which could allow it to become a major source of detailed information for such undertakings. This is true not only for initial mapping but also for updating existing maps and for continuous monitoring of these sensitive environments. SPOT's increased capabilities for vegetation discrimination make its use particularly valuable as wetland characteristics can be mapped from the extent and type of vegetation present.

Satellite imagery is used by federal and regional agencies for water resource management and control particularly in mountainous areas of the West, where it provides a convenient method for helping to predict snowmelt runoff and subsequent water yields. This type of information is essential for planning hydropower production and irrigation water allocations on a large scale.

Remote sensing has been used to monitor characteristics within large water bodies to help understand their dynamic nature and improve management practices. Current studies in the Chesapeake and Delaware Bays involve the use of SPOT Data to map sediment transport plumes, sediment densities, submerged aquatic vegetation and algal blooms.

COASTAL ZONE MANAGEMENT

The U.S. coastal zones are particularly important and sensitive environments where numerous land use/land cover types interact. Assembling comprehensive data bases and accurately mapping these extensive heterogeneous environments are essential to their management and protection. Remote sensing has been used in tidal wetland monitoring, beach erosion and barrier is-

land migration studies, though the lack of detail and insufficiently frequent coverage from previous satellites have limited the use of this data source. Now these limitations have been overcome to the point that satellite imagery can potentially play a much more significant role in these projects.

SPOT offers an increased capability for mapping land cover types, their boundary areas and inter-zone characteristics, and for assessing environmental disruption within these areas. The rapid revisit capability not only increases the opportunities for overcoming cloud cover constraints, but also allows for frequent monitoring to assess the extent and nature of change within these environments.

FORESTRY

Timber management companies use remote sensing as a tool in the management of timber resources. Crown closure assessments made from satellite imagery, combined with cartographic and field-acquired data are used as input to harvest planning, yield predictions and economic/management modeling. Remote sensing is also used to identify and map areas of disease, insect and fire damage within timber stands.

SPOT's spectral bands are particularly well suited to vegetation studies, providing the ability to distinguish many vegetation types and to identify productivity characteristics within homogeneous timber stands. Equally important to resource inventories is the increased ability of SPOT Data to delineate features such as roads, railroads and power lines, thus limiting the need to use other sources for this information. For forest managers concerned with the logistics of harvesting, such as skidding strategies and the locations of existing and planned access roads, SPOT's stereo capabilities should provide important terrain models to facilitate site engineering planning.

Research is being done by private companies to expand the applications of this technology and to develop expert systems which will determine actual ground inventories from the digital information on the imagery.

AGRICULTURE

Remote sensing is a technology useful in studying the extensive agricultural areas and rangelands in the U.S. and around the world. The imagery is used as a tool in performing up-to-date surveys of existing crops and rangelands, and estimating yields over large areas. As part of a comprehensive analysis, satellite images, weather data, soil surveys, planting records and onsite studies serve as input to planning and management decisions for agribusiness.

The three multispectral bands available from SPOT were specifically selected for their value in vegetation studies. With this spectral resolution, and the high ground resolution, SPOT has the potential to improve the level of precision in identifying different crop types, growth stages and diseased, freeze-damaged or otherwise stressed areas within orchards and croplands for crop forecasting purposes. The 10 meter ground resolution is well suited to identifying and mapping small-scale agricultural plots, and frequent coverage allows close monitoring of environmental conditions during short growing seasons.

Regional and state agencies have used remote sensing to monitor the extent and effectiveness of irrigation practices and to assist with determining future allocations of irrigation water resources on a regional basis. Similarly, satellite imagery is used to monitor the extensive rangelands in the West to determine range conditions, availability of surface water, carrying capacities and areas of overgrazing.

The U.S. Agency for International Development and the World Bank, working with Third World countries, have used satellite imagery in planning large scale agricultural development schemes in which topography, soil and water availability need to be assessed. Frequently no such information exists for these areas; satellite imagery provides a rapid, efficient means of preliminary study.

LAND USE/URBAN PLANNING

Because of the comprehensive, synoptic view that remote sensing provides, it is used by local, county and state planners as an efficient, accurate tool for creating and updating land use maps, economic analyses, resource inventories, and siting/suitability assessment studies. Many features previously undetectable on satellite imagery now become visible because of SPOT's increased resolution. These features include individual buildings, even in densely developed environments, and essential details of the transportation infrastructure. With detail approaching that of aerial photographs, SPOT's images have the potential to serve as an alternative to aerial photographic coverage, even at scales of 1:50,000 and better. This information source can be used to analyze urban, suburban and rural growth patterns, and to perform rapid population assessments and density classifications for tax planning and zoning studies.

Remote sensing is used in planning-related engineer-

ing studies such as: determining impervious surface area for urban watershed mapping and modeling; assessing the need for and siting new utility facilities and services; and planning transportation infrastructure expansion or modifications.

CARTOGRAPHY AND TERRAIN MODELING

Remote sensing has long been recognized as a powerful tool for thematic mapping, and updating and verifying information on existing maps. For many areas of the world which have never been mapped, satellite images are the only accurate source of information available from which maps can be constructed. SPOT's high resolution means the imagery can be used for detailed thematic mapping as well as the identification of individual features and small scale surface conditions. The detail and location accuracy of the image data allow the production of maps at scales of 1:50,000 and better, and reduce the need for additional information sources during map compilation. Because the imagery is available at a variety of scales and map projections, it can be used as a detailed base map and readily combined with any other geographical data bases. Through change detection analysis, SPOT can be used to efficiently update maps as often as necessary. The fact that the imagery is in digital form greatly reduces the need for additional cartographic work.

SPOT's stereoscopic imagery allows three dimensional viewing and interpretation of terrain and cultural features from any location on earth. This stereoscopic imagery is being used to produce topographic maps with contour intervals as low as 10 and 20 meters. It is also used in digital terrain modeling and the production of three dimensional perspective views for terrain simulation, strategic planning and impact assessments.

NEW APPLICATIONS

The existing user community in the U.S., as represented by the disciplines discussed above, is a crucial client base for SPOT Image Corporation. Their familiarity with the technology and their ability to realize the increased applicability of SPOT Data to much of their work is one of the elements which is essential to our success. However we are also seeing a number of exciting new uses of this technology which are inspired by the innovative capabilities of the SPOT program.

News Media

The news media is realizing that the SPOT system is particularly well suited to meet their needs. The images returned from the satellite are of high enough quality to be used for visual support in news coverage. SPOT can take pictures of any location in the world regardless of political or physical limitations. Images from the satellite were used frequently during news coverage of the Chernobyl nuclear plant accident, the Fourth of July celebration in New York City and various other events. With the rapid revisit capability and the flexibility of the imagery for use in a variety of formats, remote sensing can now be used to show and explain the dynamic nature of many newsworthy events, rather than merely present a "snapshot" in time. Remote sensing has become a powerful enough tool that, through interpretation, it can serve as an actual news gathering source or as a means of verifying a reported event.

Computerized Information Systems

SPOT can provide computerized information systems with a level of data never before available. Because of the increased information content and accuracy of the data, SPOT images contain a great deal of information such as the location of roads, railroads, power lines and ground control points, which previously had to be gathered from many different sources, digitized, and then added to the system as a separate data base. The quantity and quality of the data produced by SPOT will increase the value of these systems for creating and updating a variety of environmental data bases and for analyzing the great amount of information necessary today to support planning and management decisions.

Real estate and business information systems now have a tool which provides sufficient detail to allow the users of these systems access to the benefits of remote sensing. Individual buildings, clearly defined demographic and land use areas, transportation infrastructure and rapidly developing urban and suburban areas can all be mapped, monitored and analyzed from space prior to committing costly resources to further study or development.

One of the greatest challenges for the entire SPOT program, and especially for SPOT Image Corporation, is our goal of expanding the user community by matching SPOT's increased capabilities with new markets and applications. We look forward to meeting this goal and thus ensuring the success of SPOT and the advancement of remote sensing for the benefit of the worldwide community. ■

SPOT Image Corporation
Commercial Policy Statement
May 1988

Introduction

The launch of the SPOT 1 satellite two years ago marked the operational beginning of "commercialized" remote sensing and the transition from a primarily government supported R&D program to a commercially based, market driven industry. Today, we at SPOT are very pleased with both the progress already made and the clear direction and goals we see in the future. SPOT has demonstrated that the reliable delivery of high quality satellite data provides a foundation for commercial success. Users' "operational" information requirements are now being met with efficient and economical remote sensing solutions. Now that this initial stage has been successfully completed, the remote sensing industry is prepared to move on to the next "phase" of our business; working with our customers to establish the value of remote sensing solutions and delivering those solutions in a commercially acceptable and reliable manner. This, therefore, is an appropriate time to review what has been learned and to present SPOT's policies and plans for the future.

Initial Commercialization

SPOT's first two years have been exciting and profitable. Our initial assumption that the foundation for a financially successful industry demanded a commercial source for satellite data has been proven both by our sales revenue and by the increasing number of new users turning to SPOT. We showed that when satellite data are of high technical quality and delivery is on a reliable and commercial basis, users will have confidence in relying on our technologies and our industry as a valuable source of information in a variety of applications.

SPOT is a service oriented business. We are dedicated to providing SPOT Data as a reliable, useful and economical information tool. We have worked closely with our customers, both previous users of satellite data and new clients, in establishing the business of data supplier and solution provider. We are confident in that a sound commercial foundation has been established, but even more important is our customers' increasing acceptance of and confidence in our industry.

The Remote Sensing Industry is taking on its commercial definition. The identity and role of the major firms shaping the industry is now known. Leading "value added" service and system companies have responded to the commercialized environment by aggressively pursuing new opportunities which emphasize the use of remote sensing as an operational information tool rather than simply an R&D project opportunity. SPOT has worked closely with many of these value added firms to determine how best to identify and meet our customers' requirements and how to market our industry. Traditional economic and business criteria are now being used to define products and services to our customers. These customers are responding with a rapidly increasing interest in and reliance on our deliverables. From this initial period we have determined what SPOT's role will be as we enter this next phase of commercialization.

SPOT's Role

SPOT's primary purpose remains the reliable delivery of high quality SPOT Data products and services. We have already committed the necessary financial and business resources to ensure continuity of SPOT Data to our customers. Our global organization of receiving stations, processing centers and commercial distribution outlets is now meeting our customers' requirements on a daily and routine basis. In addition, we have a responsibility to identify and open new markets for the use of our Data and related products and services. To this end, we now also offer our customers the necessary management services which are required to transform data into information.

The most significant of these new services is the responsibility of SPOT's Project Management Group. This Group was formed to work with our customers to design and deliver cost effective

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remote sensing solutions to meet their information requirements. We offer our customers "one-stop shopping" by drawing upon the entire range of capabilities within the industry, particularly those offered by value added firms, and managing all component activities for the customer.

Our customers receive efficient and economical solutions to their problems without having to master the technologies of remote sensing or to select and coordinate various subcontractors.

We are involved in a number of joint activities with value added firms in establishing and building the commercial viability of our industry. For example, our SPOT RECOMMENDED ™ program provides our customers with a manageable selection of highly qualified value added firms whose services and products we can confidently recommend.

Our SPOT Educational and Evaluation Data Sets (SEEDS) and "Special Offer Imagery" programs are designed to meet the data requirements and economic limitations of academic users and others interested in learning more about remote sensing from working with SPOT Data. Additional promotional programs allow users to quickly and economically access SPOT's value in meeting specific information requirements.

In 1988, we will increase our support to these and similar efforts designed to increase the commercial market's awareness and acceptance of information solutions based on SPOT Data.

The Industry Today

A necessary part of the transition from what remote sensing was to what it will be is an understanding that changes in product definitions and pricing structures are inevitable. During the Landsat era, satellite data were provided from the perspective of government support to R&D studies. This dictated one set of product and pricing policies. The value of the data in particular situations, especially commercial applications, had not been established. The costs associated with acquiring and delivering the data were not subject to the business reality of a profit and loss statement. The primary objective of these programs was to get data into the hands of researchers to determine interest and applicability.

SPOT provides satellite data from a commercial perspective with business objectives. The future viability of our industry now rests on identifying commercial users whose information requirements can be met with our technology and, most importantly, on those same users determining the actual value they place on our deliverables. The value established by the marketplace must generate sufficient revenue to cover acquisition and delivery costs if our industry is to maintain its commercial status.

The costs which must be recovered are not limited to SPOT. They include the value added service firms which actually extract customer requested information from SPOT Data, and the image processing equipment manufacturers whose systems are the tools of our trade. We must all work together, recognize our inter-dependencies and share the investments necessary for developing our markets. We are well underway. The experiences of the past clearly show that there is an identifiable value for our deliverable products and services which will not only cover costs, but ensure profits. We are confident that the development of the industry is on track, on plan and on schedule for providing the necessary return on investment which is fundamental to a successful commercial venture. We recognize that it will be necessary for investments to continue, but we are equally confident that remote sensing is a sound investment and a unique and exciting business opportunity.

SPOT's Products

SPOT's standard products are the Data acquired by our satellites. Our primary mission is the collection and distribution of that unenhanced Data.

We expect that those users who require enhancement of SPOT Data products will have those needs met by value added firms at prices determined by a competitive marketplace. SPOT does not intend to offer value added or enhanced products. We may offer "non standard" products for users who require a particular data format, such as image size or scale, etc. We will always work closely with our clients and selected value added firms in producing new solutions which meet our customers' requirements or support our own market research activity. This is our market development responsibility.

Standard Data Products from SPOT will be a simplified offering of digital and photographic

products. SPOT Data serve as basic input for end users and value added firms to begin the process of information extraction. Our position at the beginning of this process requires that our products be standardized units which can meet the input specifications of various applications and activities. Our product is data with known media and format specifications. Others must be involved in transforming these products into the deliverable that meets the user's requirement. SPOT's standard products represent a commitment for what value added firms and end users can expect from us. This will allow them to develop their operations and activities based on a defined input from SPOT.

Digital products present SPOT Data in its most powerful and flexible medium. Standardized formats ensure that all computerized image processing systems from micros to mainframes can manipulate SPOT Data for maximum information extraction.

We have simplified the presentation and pricing of our film products. The film medium has the same amount of SPOT Data as the digital product, but the medium isn't as flexible. Film "freezes" the image and the information and establishes the limits for photographic based applications. These limitations explain why more and more applications are using digital media.

Although SPOT cannot increase the flexibility of film media, we can and do pay attention to the integrity and clarity of the Data. All film orders are produced by using digital enlargement techniques and producing film products directly from the CCT. In addition, customers receive Master Generation Film ™. We use no photographic enlargement or duplication processes in generating the original film products delivered to our customers.

SPOT's Pricing

The major component of our pricing policy for SPOT's products is the Data content. This reflects the successful completion of our primary mission; the SPOT satellites' acquisition of Data as programmed, receiving that Data on the ground and processing it to a standard product.

A secondary pricing component will be the deliverable medium of the product. This secondary pricing component reflects both the costs incurred producing the medium and the flexibility of information extraction available from that medium. Digital products offer the user the maximum amount of flexibility. Photographic products are the most expensive to produce. Both media include an equal amount of SPOT Data.

Over time, we expect the market to establish prices for our standard Data products which show little difference based on medium.

SPOT's Project Management Group was created in recognition of our obligation to users, especially new commercial users, to work with them in designing and delivering a complete information solution based on their business requirements and specifications. Therefore, fees for Project Management services will be established in keeping with this perspective. Although we expect this activity to cover our costs, and hopefully make a small profit, market development, not profit margin, is the underlying policy behind the service.

Satellite Acquisitions

When the SPOT 1 satellite was placed into service in 1986, fulfilling all customer orders required tasking the satellite for a specific acquisition; we had no existing archive of available images. We did recognize from the beginning, however, that in addition to meeting specific customer orders, a planned archive of Data was needed. Therefore, we have always reserved a portion of the satellite's acquisition capability for creating, updating, and maintaining SPOT's "required archive". To date, the satellite has acquired over 625,000 scenes from all over the world.

The SPOT archive has not only grown in absolute number of usable scenes, but we have listened to our customers as to which scenes are acquired. Their projected requirements are a significant input used in determining our "required archive" acquisition program. Today, over two thirds of our customers' orders are met with Data already in our archive. We will continue to devote approximately 60% of the satellite's acquisition capability to collecting images for our archive which we believe our customers will order. This process is an ongoing, interactive exchange between SPOT and our users. The Data product pricing policy applies to Data in the SPOT archive.

Customers who task the satellite to acquire a new

scene will be charged an acquisition fee for this additional service. This fee is based on the significant and growing archive of available images, and the fact that to meet customer-specified acquisition requirements involves dedicating our most important resource, time on the satellite, to that end, thereby foregoing other acquisition opportunities. This is an additional service we provide to our customers and we will charge an appropriate, market driven, fee.

The per scene fee will only apply to scenes acquired to the customer specified parameters of mode, cloud cover, angle, etc. Approximately 40% of the satellite's acquisition capability will be reserved for fulfilling individual customer's requests.

Conclusion

The policy outlined above is the commercial approach of SPOT as a business. We will continue to take the necessary decisive actions required to advance our company and our industry while always maintaining the flexibility and objectivity to respond to new developments. In 1988 we are establishing this policy and setting new fee levels based on both the realities of today's marketplace and our continued and planned investment in market development. In the future fee levels will be driven by the market place and the value determined by our customers.

Mr. SCHEUER. Thank you very much, Mr. Julyan.

And now, Dr. Anatoly Shutko, Institute of Radio Engineering and Electronics, Academy of Sciences of the Soviet Union.

STATEMENT OF ANATOLY SHUTKO, INSTITUTE OF RADIO ENGINEERING AND ELECTRONICS, ACADEMY OF SCIENCES, U.S.S.R.

Mr. SHUTKO. Thank you for inviting me to participate in this hearing on the remote sensing of the Earth. Excuse my English.

What I should like to say is the area of my specialization for more than 20 years has been remote sensing of the Earth from satellites and aircraft using radio waves.

I am here in the United States as part of a scientific exchange with the USDA, Beltsville Agricultural Research Center Hydrology Laboratory. We are discussing with specialists in this center and Goddard Space Flight Center the problems of remote sensing for soil moisture and vegetation monitoring.

I am not an official representative of the Soviet side at the hearing and I am participating in it only as a specialist.

Concerning the topic of the hearing I can state the following.

Observations conducted from satellites of the Landsat series have played a valuable role in scientific research and practical applications and many consumers in the world would appreciate getting the data in the future.

In the USSR, more or less adequate observations were conducted from satellites of the Meteor series.

Last year, the Soviet Union demonstrated a new optical system which permits one to obtain color photos with a 5 to 10 meter spatial resolution. These photos are available for delivery from the USSR on a commercial basis.

As stated by Mr. Kolosov, the official Soviet representative, at the International Study Week on "Remote Sensing and its Impact on Developing Countries: that took place in the Vatican City in 1986 (we both participated in the study week), Soviet organizations are open for contacts with consumers on a commercial basis and the main problem here is that potential consumers do not know the details of possible commercial agreements.

The contacts between consumers and Soviet organizations which supply the satellite data, in particular the high resolution photos mentioned above, may be obtained through such organizations as Glavcosmos, Soyuzcarta, headed by Mr. Piskulin, State Center, and Pryroda, headed by Mr. Kiyenko.

At the International Congress on Photogrammetry and Remote Sensing that took place in Kyoto last year, Soviet representatives from these organizations exhibited photos taken over areas of Japan. Japanese specialists have expressed an interest to these photos and some of the photos were given to them.

A good example of giving satellite data to many consumers was demonstrated over the past few years with the Cosmos 1500 satellite. The data from its optical and active radar sensors was available to different countries.

Concerning some other programs and ideas I can state the following. One of the newest programs is the Priroda (Nature) project, headed by Professor N. Armand and scheduled for the early 1990s.

It includes observations at optical, infrared, and radio waves, and the data may be used for scientific and practical application.

In order to increase the effectiveness of remote sensing—it's my opinion as a specialist—the observations must be expanded beyond the optical bands to include microwaves. I mean not only optical bands but microwaves.

Microwave radiometric measurements are very important for quantitative soil moisture observations and ocean surface temperature mapping. These observations are important for monitoring the Earth from satellites for hydrological, meteorological, and ecological purposes which are critical to global studies. Research in the USA is being conducted cooperatively by the USDA Agricultural Research Service Hydrology Laboratory and organizations of NASA. In the USSR, this research is conducted by the Institute of Radioelectronics and Engineering of the USSR Academy of Sciences and the General Geophysical Observatory of State Committee on Hydrometeorology.

Microwave radiometers are now used in operational applications in the USSR for the last five years as aircraft sensors for agriculture, irrigation, water management, etc. And these observations, in particular the sensors, are now operating for commercial exchange with other potential consumers.

Thank you for listening to me.

[The prepared statement of Mr. Shutko follows.]

Dr. Anatoli Shutko
Institute of Radioengineering and Electronics
USSR Academy of Sciences
Moscow, USSR

May 8, 1989

Thank you for inviting me to participate in the hearing on remote sensing of the Earth. My area of specialization for more than 20 years has been remote sensing of the Earth from satellites and aircraft using radio waves.

I am here in the United States as part of a scientific exchange with the USDA, Beltsville Agricultural Research Center Hydrology Lab. We are discussing with specialists in this Center and Goddard Space Flight Center the problems of remote sensing for soil moisture and vegetation monitoring.

I am not an official representative of the Soviet side at the hearing and I am participating in it only as a specialist.

Concerning the topic of hearing I can state the following:

1. Observations conducted from satellites of the "Landsat" series have played a valuable role in scientific research and practical applications and many consumers in the World would appreciate getting the data in future;
2. In the USSR more or less adequate observations were conducted from satellites of the "Meteor" series;
3. Last year, the Soviet Union demonstrated a new optical system which permits one to obtain color photos with a 5 to 10 meters spatial resolution. These photos are available for delivery from USSR on a commercial basis;
4. As stated by Mr. Kolosov, the official Soviet representative at the International Study Week on "Remote Sensing and Its Impact on Developing Countries" that took place in the Vatican City in 1986 (we both participated in that Study Week) Soviet organizations are open for contacts with consumers on a commercial basis and the main problem here is that potential consumers do not know the details of possible commercial agreements;
5. The contacts between consumers and Soviet organizations which supply the satellite data, in particular the high resolution photos mentioned above may be obtained through such organizations as "Glavcosmos", "Soyuzcarta" headed by Mr. Piskulin, State Center and "Pryroda" headed by Mr. Kiyenko;
6. At the International Congress on Photogrammetry and Remote Sensing that took place in Kyoto last year, Soviet representatives from these organizations exhibited photos taken over areas of Japan. Japanese specialists have expressed an interest to these photos.
7. A good example of giving satellite data to many consumers was demonstrated over the past few years with the "Cosmos 1500" satellite. Data from its optical and active radar sensors was available to different countries.

Concerning some other programs and ideas I can state the following:

1. One of the newest programs is the "Priroda (Nature)" project headed by Prof. N. Armand and scheduled for the early 1990s. It includes observations at optical, infrared, and radio waves and the data may be used for scientific and practical application;
2. In order to increase the effectiveness of remote sensing the observations must be expanded beyond the optical bands to include microwaves;

3. Microwave radiometric measurements are very important for quantitative soil moisture observations and ocean surface temperature mapping. These observations are important for monitoring the Earth from satellites for hydrological, meteorological, and ecological purposes which are critical to global studies. Research in the USA is being conducted cooperatively by the USDA Agricultural Research Service Hydrology Lab and NASA. In the USSR this research is conducted by the Institute of Radioelectronics and Engineering of the USSR Academy of Sciences and the GGO of State Committee on Hydrometeorology);

4. Microwave radiometers have been used in operational applications in the USSR for 5 years as aircraft sensors for agriculture, irrigation, water management, etc.

Mr. SCHEUER. Thank you, Dr. Shutko.

And now Mr. Myron Laserson, ContiTrade Services Corporation, and the Continental Grain Company. You can explain if you will and elaborate the relation between those two. Please proceed, Mr. Laserson.

STATEMENT OF MYRON LASERSON, CONTITRADE SERVICES CORPORATION, CONTINENTAL GRAIN COMPANY, NEW YORK, NEW YORK.

Mr. LASERSON. Thank you, Mr. Chairman.

I'd like to clarify a statement that Dr. Shutko made earlier. We signed as ContiTrade in March of this year an agreement with Soyuzkarta to be their exclusive sales representative in the United States and in the Western Hemisphere. And while obviously we will work with everybody, that arrangement is now clarified. So we will answer the questions that come to us representing Soyuzkarta in this country.

In addition to the remarks that I put in the official record, with your permission, Mr. Chairman, I'd like to talk about two issues that are not covered in those remarks.

The first issue is to talk about the relationship with Continental Grain and the industry that has benefitted from 25 years of agricultural trade with the Soviet Union. At times that trade has been 25 percent of the U.S. grain trade.

Our overall trade with the Soviet Union from the United States is quite small. We export practically no consumer goods despite the Soviet needs, and we import less from the Soviet Union than does Switzerland.

Our job in ContiTrade is to identify Soviet products that can sell in the West where the quality is acceptable. The business in itself can be profitable. Equally important, the Soviets have agreed in principle to spend the earned foreign exchange on goods they need to buy. As they improve their product they will sell their goods elsewhere and a chance for the United States to sell other goods from other industries will grow in proportion.

I would call the committee's attention to the fact there are 280 million people in the Soviet Union who have no private debt and they have 20 million reasons to prefer buying goods from the United States when they can as opposed to buying them from other countries. And I put that in the context of our foreign trade problems.

The second issue is the issue of policy. The Soviets are making a serious effort to overcome their ingrown reservations about sharing their technology with the West. We, of course, are encouraging that trend.

After considerable negotiations, the Soviets have granted to us the unconditional right to merge their product with that of competitors, such as SPOT and EOSAT, so as to make a superior product capturing the best qualities of each. We are currently actively working with EOSAT on one or more such products and as we achieve success with the experimental phase we expect to increase the data flow and we are encouraged that we will be able to work in the direction of using data of the socialist world.

Another example of information sharing is the decision to hold an exhibition here in Washington on June 21st to explain in detail the Soviet program and to display an inventory of upward of 300 scenes of various parts of the world.

The benefits of sharing space information impact all of us. They include lessening the risk of nuclear war to effective monitoring of drugs and crime. These are issues that cross borders and we are proud to play our part in helping the Soviets join the world community.

Thank you very much.

[The prepared statement of Mr. Laserson follows.]

STATEMENT OF M.R. LASERSON, SENIOR MANAGING DIRECTOR
CONTITRADE SERVICES CORPORATION, NEW YORK

Before the Committee on Science, Space and Technology,
Subcommittee on Natural Resources, Agriculture Research
and Environment
And Subcommittee on International Scientific Cooperation.
JOINT HEARING ON LONG-TERM FUTURE OF THE LANDSAT SYSTEM
May 9, 1989

Mr. Chairman and Members of the Committee:

My name is Myron R. Laserson and I am Senior Managing Director of ContiTrade Services Corporation, a wholly owned subsidiary of Continental Grain Company.

I am delighted to appear before your Committee and I will offer this statement that describes ContiTrade's contract with the Soviet agency Soyuzkarta as well as the space data we will be marketing.

Continental Grain is a 175 year old international business involved in commodity trading, commodity processing and related financial services. ContiTrade Services has the exclusive right to market high resolution Soviet satellite imagery within the Western Hemisphere, with limited exceptions in Latin America. Coverage includes all parts of the world except for the USSR and the Socialist nations.

The two major items we will be marketing are the KFA-1000 and the MK-4 photography.

KFA-1000 PHOTOGRAPHY

KFA-1000 photography is available in both panchromatic and color products, as film positives or negatives and as photographic prints.

Original scale is approximately 1/250,0009 or 30 x 30 cm film, but scales are large as 1/25,000 are also available. Each photograph covers about 60 by 60 miles, and there is normally a 60% north-south overlap for stereoscopic coverage. Each film has five fuducial points.

Characteristics of the KFA-1000 camera are:

Focal Length: 1000 mm
Frame Format: 300 x 300 mm
Scale: 1/220-280,000
Longitudinal Overlap: 60%
Width of Survey Band by 2 Cameras: 120 km and more

Spectral Zones of the Layers: 570-670 nanometers
670-810 nanometers
Photofilm types: Spectrozonal two-layer
Resolution: 5 meters

The color film is spectrozonal, with two individual emulsion layers. The color of the final photographic product depends on the number of filters employed during processing. Two filters produce a pinkish tone and three filters produce a more natural earth tone.

All photographic reproduction is done only from master original film negatives brought down from the satellites. Only first generation derivative products are marketed.

The resolution of the KFA-1000 photography is normally about 5 meters. The resolution may vary slightly due to atmospheric conditions and surface reflectivity. Some researchers have reported resolution finer than 2 meters.

The KFA-1000 is a photographic product, but CTS is developing technology to digitize these materials at a pixel size of about 12 microns to provide it to customers in a digital format compatible with Eosat and SPOT without loss of resolution or rectification.

Delivery time for photographic products is normally about three weeks for archival materials. If archival coverage is not available, CTS will contract to obtain new coverage at the same price as archival data.

Any scene that has more than 25% cloud cover (by CTS calculations) will be reduced in price directly proportional to the percentage of cloud cover.

Special service products are also available. CTS will rectify any scene to any map of the choice of the customer if the map is supplied by the customer. Cartographic and thematic interpretation services are also available.

Data may be purchased for any parts of the world, excluding USSR, Eastern Europe, People's Republic of China, Vietnam, North Korea, Afghanistan, Mongolia, Nicaragua and Cuba. Special acquisition in these areas will be considered.

MK-4 PHOTOGRAPHS

MK-4 photographs were made available for the first time for purchase on December 8, 1988, coinciding with the General Secretary Gorbachev's visit to New York City. The MK-4 is the most sophisticated of the Soviet Union's large format topographic cameras whose products are being marketed by ContiTrade Services.

The MK-4 is a true multi spectral camera with data recorded on four separate black and white film bases which may be combined to produce a false color image. The resolution of the MK-4 is about 6 meters and the product is excellent for cartographic and demographic surveys. The film contains 25 fudicial points, enabling very high accuracy in enlargements.

The selected characteristics of the MK-4 are:

Number of Channels: 4
Focal Length: 300 mm
Frame format: 180 x 180 mm
Scale (depending on altitude of survey): 1:650000 - 1:1500000
Longitudinal overlap: 60%
Width of the Survey Banks: 120-270 km
Possible spectral zones of channels (NM): 635-690
810-900
515-565
460-505
580-800
400-700
Type of the used photofilms: Black and White, spectrozonal, two-layer
Resolution: 6 meters

Only photographic products are available at this time. These are available as film negatives or positives, and prints. All products are available in either black and white or color. Enlargements to scales as much as 1/25,000 are available.

During the latter part of 1989, digitized products obtained from original negatives with pixel size of less than 10 microns should be available on magnetic tapes. These will be in formats compatible with Eosat and SPOT.

New coverage can be contracted with ContiTrade Services for future acquisition with no additional surcharge. Normal delivery time for archival data is three weeks. New coverage acquisition will be on a negotiated time frame.

Data may be purchased for any parts of the world excluding USSR, Eastern Europe, PRC, Vietnam, North Korea, Afghanistan, Mongolia, Nicaragua and Cuba. Special acquisition in these areas will be considered.

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Mr. SCHEUER. Well, we're all eager to see the Soviets join the world community and we're seeing more and more evidence of that all the time. It's a sea change that's developing in the relationship between the Soviet Union and the world community and we welcome all of the variegated and miscellaneous evidences of that enormous sea change coming up.

We will now hear from Mr. Tasuguo Tadakawa, Director of the NASDA office, and he is accompanied by Takuji Yamagami, Director of External Relations for NASDA.

Please take your five minutes, Mr. Tadakawa, and your full statement will be printed in the record at this point.

STATEMENT OF TSUGUO TADAKAWA, NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN, DIRECTOR, WASHINGTON, D.C. OFFICE; ACCOMPANIED BY TAKUJI YAMAGAMI, DIRECTOR, EXTERNAL RELATIONS, NASDA, TOKYO, JAPAN.

Mr. TADAKAWA. Thank you, Mr. Chairman.

Please excuse my English. It is my pleasure and honor to be here to present our views.

In 1972, the first Earth observation satellite was launched, later renamed Landsat 1, and a number of investigators from Japan participated in this program by providing satellite data analysis. That was an initial step in satellite remote sensing activities. In 1979, direct reception of Landsat data in Japan allowed researchers from various organizations and universities an opportunity for involvement in the remote sensing activities. During the middle of the 1970s, influenced by the success of the Landsat program, NASDA, supported by groups of experts, started initial study of Japanese needs and contributions in the field of remote sensing. The Space Activities Commission of Japan, our policy making organization in Japan, recommended in its report "Outline of Japanese Space Policy," that a series of marine and land observation satellites should be developed in order to first establish Earth observation technology and then move on to operational satellites. This recommendation resulted in development of two remote sensing satellites, namely Marine Observation Satellite—we call it MOS-1—and Earth Resources Satellite, ERS-1. These satellites are designed to contribute to the needs of satellite remote sensing data users whose overall requirements are not fulfilled by Landsat data.

In February 1987, NASDA successfully launched the first Japanese Earth Observation Satellite, MOS-1. NASDA has been receiving, processing, archiving and distributing MOS-1 data. MOS-1 has a Visible Near Infrared Instrument, called MESSR, which has a 50-meter spatial resolution. ESA, Canada, Thailand, Australia are now receiving MOS-1 data at their ground stations.

ERS-1 is now in critical design phase planning for a launch in early 1992. ERS-1 will carry a Synthetic Aperture Radar and a multispectral imaging radiometer with high geometric resolution. Arrangement for direct reception of ERS-1 data have been made with NASA and are now being negotiated with Canada, ESA and other agencies.

Japan now plans to launch the Advanced Earth Observing Satellite—we call it ADEOS—around 1994 as the next generation Earth

observation satellite. ADEOS will carry two core advanced optical sensors. In addition to those sensors, ADEOS will provide the international community with opportunities to apply their sensors on ADEOS. Two core sensors of ADEOS are the Ocean Color and Temperature Scanner, OCTS, and the Advanced Visible and Near Infrared Radiometer, AVNIR. AVNIR is an advanced sensor which has higher resolution than the MOS-1 and ERS-1 sensors. It's 16 meter in all spectral band and 8 meter in panchromatic mode. We are preliminarily examining two sensors from NASA and a sensor from France. Our final selection will take place this August.

We also are going to participate in the International Polar Platform of NASA which is part of the international space station program with the two sensors, namely the advanced microwave scanning radiometer AMSR and the intermediate thermal infrared radiometer, ITIR.

I would like to address our views on the commercialization of satellite remote sensing.

We still believe that commercialization of satellite remote sensing is premature and will not become matured in the near future. Our experience shows us that the cost of receiving, processing, archiving, and distributing high spatial resolution data from MOS-1, SPOT-1, and Landsat-5 in Japan far exceeds the revenue received for the data. This cost even does not include satellite development and launch cost.

Since we are still in the initial stage of understanding Earth phenomena through the use of satellite remote sensing technology, our main purpose for utilizing satellite remote sensing is to develop its technology and provide the data for the users who intend to develop and demonstrate the activities for the benefit to the public.

To promote maximum benefit to the public by satellite remote sensing activities, NASDA recognizes the importance of two basic principles of Earth observation, namely the Open Sky policy and Non-discriminatory Data Distribution, and NASDA will use its best effort to make the data from our satellites available to anyone in the world.

Recently, global change, such as the greenhouse effect, et cetera, has become a major concern of the people of the world. This is challenging for all humankind. The most effective way to measure, monitor and assess global change is, of course, through satellite remote sensing. Since monitoring global change will require many instruments other than our visible and near infrared instrument, we strongly believe that international satellite remote sensing cooperation is indispensable.

The Japanese answer to global change is obviously ADEOS and possibly the tropical rainfall measurement mission we wait for the conclusion by both governments.

Finally, Japanese Landsat data users are very much concerned about the continuation of Landsat 4 and 5. The president of this country clearly stated in signing an executive order of the National Space Council that space development needs coherence, continuity and a commitment. That's absolutely right. I believe that the U.S. Government and the Congress wisely choose to continue to operate Landsat 4 and 5 and to take appropriate measures for Landsat 6.

This completes my statement. Thank you.

[The prepared statement of Mr. Tadakawa follows.]

STATEMENT
OF
Mr. Tsuguo TADAKAWA
NATIONAL SPACE DEVELOPMENT AGENCY
OF
JAPAN
(NASDA)
Director
NASDA Washington, D.C.OFFICE

before the
Subcommittee on Natural Resources,
Agriculture Research, and Environment
and the
Subcommittee on International Scientific Cooperation
Committee on Science, space and Technology
United States House of Representatives

May 9, 1989

Good morning, Mr. Chairman and Distinguished Members of the subcommittees. I am Tsuguo Tadakawa. I have been representing the National Space Development Agency of Japan (NASDA) in Washington, D.C. for the last three years.

It is a privilege for me to appear before you to present our views concerning International Cooperation in Satellite Remote Sensing.

Firstly, I will briefly describe the history of Japanese Satellite Remote Sensing Activities. Then I will explain our current and future plans for remote sensing activities including international collaboration. Lastly, I will touch upon the issues of commercialization of satellite remote sensing.

Before Japan became one of the countries which operate its own remote sensing satellites, NASDA had been receiving, processing, and archiving Landsat Data at its Earth Observation Center (EOC) near Tokyo since 1979. Those activities were realized by the agreement between NASDA and NASA, which was later applied between NASDA and NOAA, for receiving and processing of Landsat data. And those data have been distributed to the public as agreed at a fair and reasonable charge in a non-discriminatory manner through Remote Sensing Technology Center (RESTEC). RESTEC is a non-profit organization which distributes satellite remote sensing data under a contract with NASDA.

The U.S. Landsat Program implemented by NASA/NOAA has encouraged and helped us to promote our own remote sensing activities. Having opportunity to receive and to process Landsat data, we recognized the necessity of the satellite remote sensing in Japan.

Let's turns our eyes to the current world remote sensing activities. France has been operating her remote sensing satellite, SPOT, since 1986, and its data are commercially available throughout the world. We launched our Marine Observation Satellite (MOS-1) in 1987 and its data are also available to the public. There are many countries which receive those satellite data. I believe that several countries have also plans to launch their own remote sensing satellite and some other countries are planning to receive those data as well. This proves that there are a lot of countries which have and will have a plan to use satellite remote sensing data for their national and regional activities and also proves that remote sensing activities have been steadily growing worldwide.

Civil land remote sensing activities originated with the U.S. Landsat Program. Many users in Japan are undoubtedly expecting to be provided with Landsat data that will allow them to proceed with their research and applications. According to Japanese researchers and users, Landsat data are very important for their activities and as a standard for the other satellite remote sensing data.

It was with great concern that Japanese Landsat data users learned that the United States Government and Congress were proposing no additional funds for operating Landsat 4/5. We strongly hope that the future of the U.S. civilian remote sensing system will be determined by considering the mission needs of the world and request for continuous operation of Landsat as the world's leading system. We also hope that its data will be provided continuously to world users.

In 1972, the first earth observation satellite ERTS (Landsat-1) was launched and a number of investigators from Japan participated in this program by providing satellite data analysis. That was an initial step in satellite remote sensing activities. In 1979, direct reception of Landsat data in Japan allowed researchers from various organizations and universities an opportunity for involvement in the remote sensing activities. At that time, we found that the wider the interests in various field grew, the more diverse the need. During the middle of the 70s, influenced by the success of the Landsat program, NASDA, supported by groups of experts, started initial study of Japanese needs and contributions in the field of remote sensing. The Space Activities Commission of Japan (SAC), which supervises space activities in

Japan, recommended in its report "Outline of Japanese Space Policy" that a series of marine and land observation satellites should be developed in order to first establish earth observation technology and then move on to operational satellites. This recommendation resulted in development of two remote sensing satellites, namely Marine Observation Satellite (MOS-1) and Earth resources Satellite (ERS-1). These satellites are designed to contribute to the needs of satellite remote sensing data users whose overall requirements are not fulfilled by Landsat data.

In Feb. 1987, NASDA successfully launched the first Japanese Earth Observation Satellite, MOS-1. NASDA has been receiving, processing, archiving and distributing MOS-1 data. MOS-1 has a Visible Near Infrared Instrument, called MESSR. ESA, CCRS of Canada, NRCT of Thailand, and CSIRO of Australia are now receiving MOS-1 data at their ground stations.

NASDA started the direct reception of SPOT-1 data in October 1988, and RESTEC has been distributing SPOT data since January of this year.

ERS-1 is now in critical design phase planning for a launch in 1992. ERS-1 will carry a Synthetic Aperture Radar (SAR), which uses a different frequency band than does the European ERS system, and a multispectral imaging radiometer with high geometric resolution. Arrangement for direct reception of ERS-1 data have been finalized with NASA and are being negotiated with CANADA, ESA and other agencies.

Japan now plans to launch the Advanced Earth Observing Satellite (ADEOS) around 1994 as the next generation earth observation satellite. ADEOS will carry two core advanced optical sensors. In addition to these sensors, ADEOS will provide the international community with opportunities to embark their sensors on ADEOS, and will contribute to the progress of earth observation. The Announcement of Opportunity (AO) for participation in this program has been issued to related organizations and individual researchers in the international community. Two core sensors of

ADEOS are the Ocean Color and Temperature Scanner (OCTS) and the Advanced Visible and Near-Infrared Radiometer (AVNIR). AVNIR is an advanced sensor which has higher resolution than the MOS-1 and ERS-1 sensors. For the participation from the international community, sensors from NASA and CNES of France are the candidate ones in response to the AO.

Polar Platforms contributed by NASA and ESA in the international Space Station Program gives us an opportunity to participate in remote sensing activities. Japan is now proposing the Advanced Microwave Scanning Radiometer (AMSR) and the Intermediate Thermal Infrared Radiometer (ITIR) for flight on the NASA platform.

A brief description of the sensors which I have mentioned before is attached to this statement.

I would like to address our views concerning issues related to the commercialization of satellite remote sensing.

We still believe that commercialization of satellite remote sensing is premature, and will not become matured in the near future. Our experience shows us that the cost of receiving, processing, archiving, and distributing high spatial resolution data from MOS-1, SPOT-1, and Landsat-5 in Japan far exceeds the revenue received for the data. This cost even does not include satellite development and launch cost.

Since we are still in the initial stage of understanding earth phenomena through the use of satellite remote sensing technology, our main purpose for utilizing satellite remote sensing is to develop its technology and to provide the data for the users who intend to develop and demonstrate the activities for the benefit to the public.

To promote maximum benefit to the public by satellite remote sensing activities, NASDA recognizes the importance of two basic principles of Earth Observation, namely the "Open Sky" and "Non discriminatory Distribution", and NASDA will use its best effort to make the data from our satellites available to anyone in the world.

Recently, "Global Change" has become a major concern to the people of the world. This is a challenging theme for all humankind. The most effective way to measure, monitor and assess "Global Change" is , of course, through Satellite Remote Sensing. Since monitoring "Global Change" will require many instruments other than our Visible and Near Infrared instrument, we strongly believe that international Satellite Remote Sensing Cooperation is indispensable.

NASA and NOAA have made big progress in this field since the beginning of 1970s. NASDA, as a newcomer to Earth Observation, pays sincere respect to these agencies for these achievements and their roles as pioneers. Nowadays international collaboration is essential in this field. NASDA would like to promote satellite remote sensing collaboration and to take an important role for the future of mankind. Such efforts, exemplified by development and launch of ERS-1, ADEOS and so on, will come to fruition on several joint NASA/NASDA programs, such as direct reception of Japanese ERS-1 satellite data at the Fairbanks Station in the State of Alaska and the Tropical Rainfall Measurement Mission. Furthermore, international participation in future remote sensing satellites will strengthen world-wide efforts, such as NASA providing instruments for NASDA's ADEOS satellite, and NASDA providing an instrument on NASA Polar Orbiting Platform.

We will continue to conduct satellite remote sensing programs emphasizing international cooperation for efficient promotion of remote sensing.

Thank you.

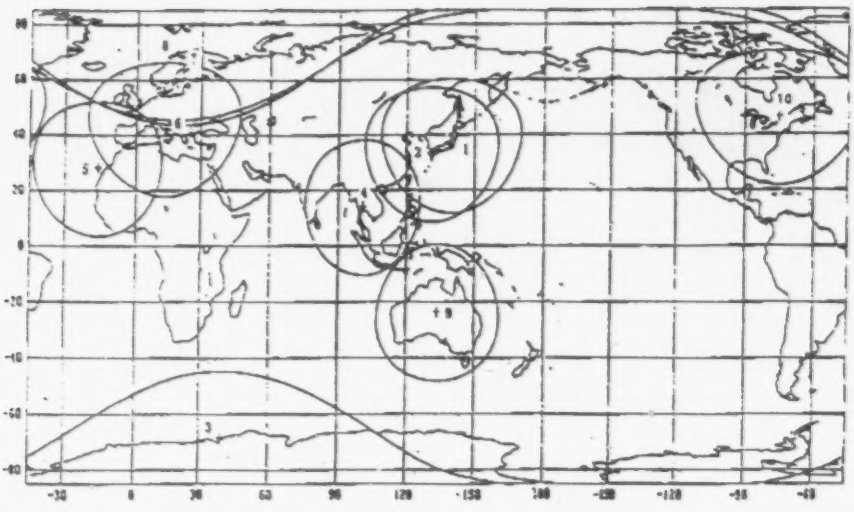
MOS-1 Specification

Item	Parameter
Orbit	Near-Polar (909km) Sun-Synchronous (Local Mean Time 10:05AM) 17 days Coverage Cycle
Weight	740kg
Power	Solar Arrey 640(BOL)W
Stabilization	3-Axis, Earth-Pointing
Launch Vehicle	N-II from TNSC
Design Life	2 Years
Instruments	MESSR (Multispectral Electronic Self Scanning Radiometer) VTIR (Visible and Thermal Infrared Radiometer) MSR (Microwave Scanning Radiometer) DCS (Data Collection System)
Launch date	Feb. 19, 1987
Status	In operation

Characteristics of MOS-1 Sensors

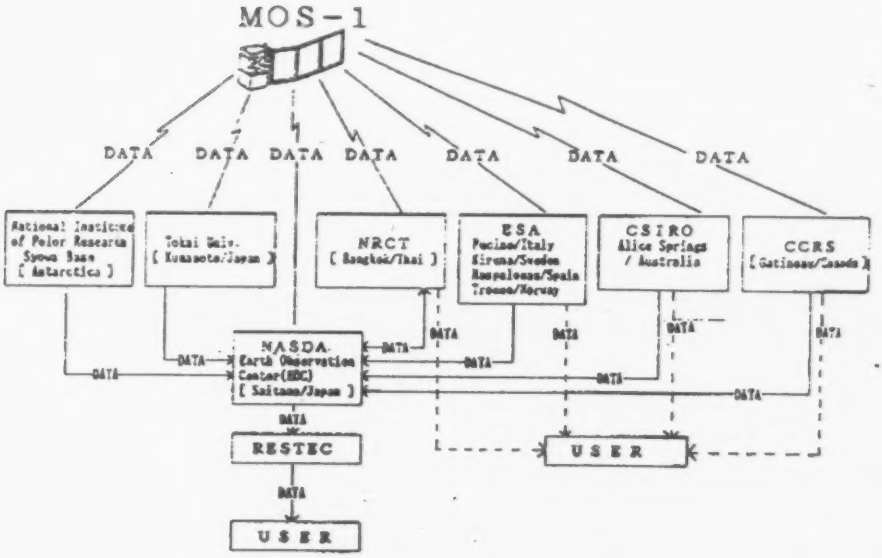
Item \ Sensor	MESSR	VTIR		MSR	
Wavelength (μm)	0.51 - 0.59 0.61 - 0.69 0.72 - 0.80 0.80 - 1.1	0.5 - 0.7	6.0 - 7.0 10.5 - 11.5 11.5 - 12.5	———	
Frequency (GHz)	———	———	———	23.8	31.4
Geometric Resolution (IFOV in km)	0.05	0.9	2.7	32	23
Radiometric Resolution	(35dB)	55dB* (Alb.=80%)	0.5K	1K	1K
Swath width (km)	100 (one optical element) x 2	1500		320	
Scanning Method	electric	mechanical		mechanical	

Remarks * Signal to noise ratio excluding quantization noise.



1. EOC 2. Kumamoto 3. Syowa-base 4. Bangkok
5. Maspalomas 6. Fucino 7. Kiruna 8. Tromsö
9. Alice Springs 10. Gatineau

World Coverage Map of MOS-1



MOS-1 data distribution flow

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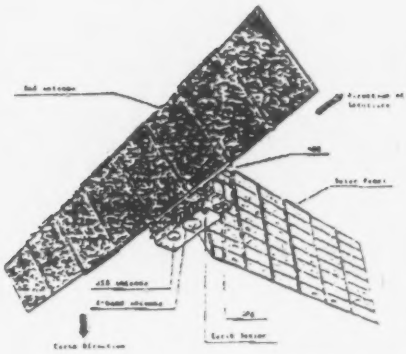


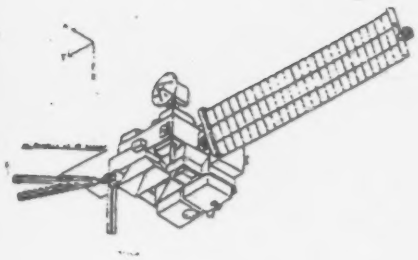
ERS-1 Configuration

ERS-1 Specification

Item	Parameter
Orbit	Sun-asynchronous
Altitude	Approx. 568 km
Inclination	Approx. 97.7°
Recurrent period	44days(Westward)
Local mean time (descending)	10:30-11:00AM
Number of orbit per day	Approx. 15
Weight	Approx. 1400 kg
Launch Vehicle	H-I Rocket
Design Life	2 Years
Launch Schedule	Early 1992

Characteristics of ERS-1 Sensors

Item \ Sensor	SAR	OPS			
		Band	Center Wavelength	Band width	Note
Wavelength (μm)	L-band	1	0.56	0.08	
		2	0.66	0.06	
		3	0.81	0.10	Band4 is for off nadia viewing.
		4	0.81	0.10	
		5	1.655	0.11	Band3 and 4 makes a stereo-pair.
		6	2.065	0.11	
		7	2.19	0.12	
		8	2.335	0.13	
Polarization	H-H	———			
Band number	1	8 (approximately)			
Spatial resolution (meter, squares)	18 (approximately) (3 look)	18 x 24 (approximately)			
Off Nadia Angle (degrees)	35	15.33 (Band4 only)			
Swath Width(Km)	75 (approximately)	75 (approximately)			
Stereoscopic Imaging Capability	———	Yes			



ADEOS Conceptual Drawing

ADEOS Specification

Item	Parameter
Orbit	Sun-synchronous (Approx. 800km)
Weight	Approx. 3000 kg
Power	Approx. 3.5 kw
Launch Vehicle	H-II Rocket (Dual Launch)
Design Life	3 Years
Launch Schedule	FY 1994

Characteristics of ADEOS Sensors

OCTS(Ocean Color and Temperature Scanner)	
Spectral Channels	Visible 8 Channels Near-Infrared 2 Channels Middle-Infrared 1 Channel Thermal-Infrared 3 Channels
FOV	±40 Degree(1400 km at the altitude of 800 km)
IFOV	0.65 mRAD(0.7 km at the altitude of 800 km)
Data Rate	2.1 MBPS
Weight	180 kg
Power	240 W

AVNIR(Advanced Visible and Near Infrared Radiometer)	
Spectral Channels	Visible 3 Channels Near-Infrared 1 Channel
FOV	4.6 Degree(65 km at the altitude of 800 km)
IFOV	20 μRAD(16 m at the altitude of 800 km)
Pointing Angle	±40 Degree(1500 km at the altitude of 800 km)
Data Rate	100 MBPS
Weight	200 kg
Power	250 W

AO Sensors (AO:Announcement of Opportunity)	
Total Weight	Approx. 200 kg
Total Power	Approx. 300 W
Volume	TBD
Thermal	Self Dissipation
Data Rate	< 100 MBPS
FOV	TBD
Schedule	AO Release Sep. 1987 Deadline for Receipt End of 1987 Selection Middle of 1988

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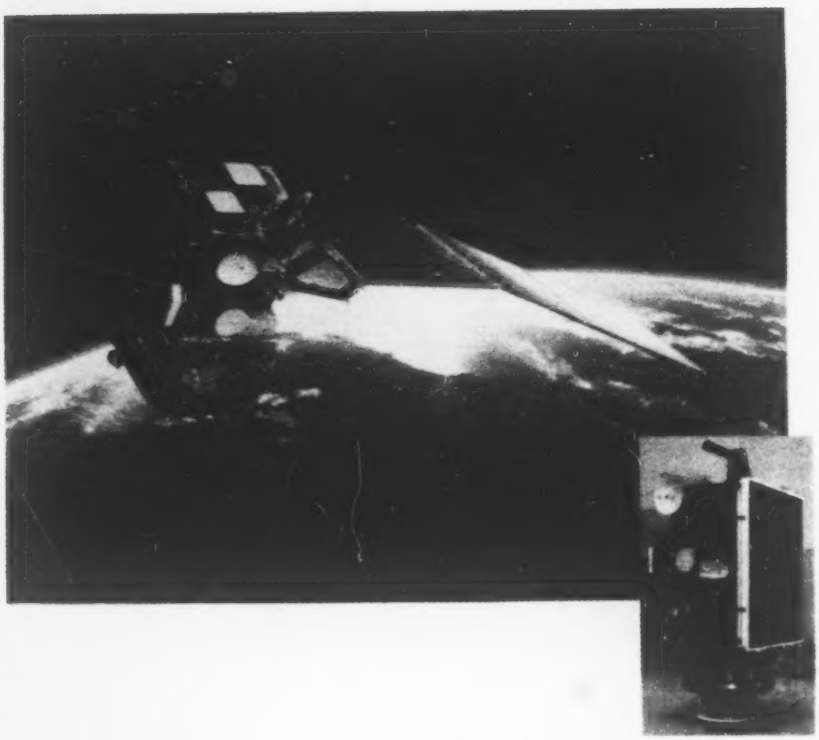
Characteristics of AMSR and ITIR

	AMSR ADVANCED MICROWAVE SCANNING RADIOMETER	ITIR INTERMEDIATE THERMAL INFRARED RADIOMETER
BASIC SPECIFICATION (TENTATIVE)	· FREQUENCY 6.6, 10.65, 18.7, 23.8, 31.55 GHz · SPATIAL RESOLUTION 9.2 - 38 km · SWATH WIDTH 1,200 km	· WAVELENGTH 0.85 - 11.7 μm (NUMBER OF BANDS: 12) · SPATIAL RESOLUTION 15m (NIR/SWIR) 60m (TIR) · SWATH WIDTH 30km
OBJECTIVES	· OCEAN AND ATMOSPHERE OBSERVATION · DATA CONTINUITY OF ADEOS-I NSR	· MINERAL RESOURCES OBSERVATION · GEO-THERMAL OBSERVATION
TECHNOLOGICAL FEATURES AND EXPECTING RESULTS	· MULTI-BAND OBSERVATION · ESTABLISHMENT OF TECHNOLOGIES REQUIRED FOR LOW NOISE RECIEVER AND LARGE ANTENNA · ELECTRICAL SCANNING	· PUSH-BROOM TYPE SENSOR SYSTEM · ESTABLISHMENT OF TECHNOLOGIES REQUIRED FOR HIGH RESOLUTION OBSERVATION · MULTI-BAND SENSOR COVERING NEAR INFRARED THROUGH THERMAL INFRARED WAVELENGTH

海洋観測衛星
Marine Observation Satellite

NASDA



MOSの概要

海洋観測衛星（MOS）は、地球資源の有効利用、環境の保全等に資する人工衛星による地球観測システムの開発の一環として開発された我が国初の地球観測衛星です。海洋観測衛星1号（MOS-1）は、昭和62年2月19日に、種子島宇宙センターから、N-IIロケットにより打ち上げられました。MOS-1の後継機として、現在MOS-1bが開発されており、この衛星は昭和64年度に打上げ予定です。これらの衛星の3つの放射計とデータ収集システムにより取得されるデータは、海洋資源の確保や有効利用だけでなく、農林業や環境状況のモニタ等にも利用できるものと期待されています。

Outline of Marine Observation Satellite

Marine Observation Satellite (MOS) is Japan's first earth observation satellite developed domestically. It will be part of a system for earth observation by satellite that will contribute to the effective use of the earth's resources and the conservation of its environment. Marine Observation Satellite-1 (MOS-1) was launched on February 19, 1987 from the Tanegashima Space Center by the N-II rocket. The MOS-1b as a succeeding satellite to the MOS-1 is being developed and will be launched in 1990 by the H-I rocket.

It is expected that ther data collected by three radiometers and a data collection platform of each satellite will be useful not only to use marine resources efficiently but also to monitor agricultural, forestry and environmental conditions.

開発の目的と経緯

MOSにはMOS-1及びMOS-1bがあり3種類の観測機器で地表面の画像を撮像します。

MOS-1は、次のような目的で開発されました。

・地球観測衛星の基本技術の確立
・搭載放射計の開発及び機能・性能の確認並びにこれらによる海洋を中心とした地球全般の実験観測
・データ収集システム(DCS)の基礎実験

MOS-1bはMOS-1の後継機としてそのプロトタイプモデルをリハービッシュするもので、開発目的は次のとおりです。

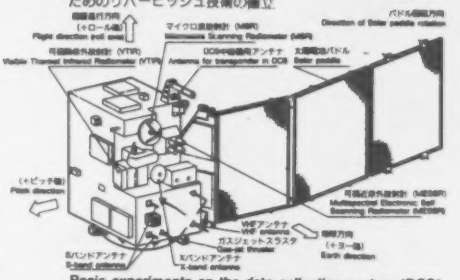
・3種類の観測機器及びデータ収集システムによる海洋を中心とした地球全般の観測の継続

Development Purpose and History

The MOS consists of two satellites: MOS-1 and MOS-1b. The satellites will use three types of observation sensors to take pictures of the earth surface.

The mission objectives of the MOS-1 are as follows:

- Establishment of fundamental technology for earth observation satellites
- Experimental observation of the earth, in particular the oceans; development of observation sensors; verification of their functions and performance
- MOS-1とMOS-1bの2衛星運用を含む地球観測衛星システムの運用技術の確立
- 衛星のプロトタイプモデルをフライトモデルにするためのリハービッシュ技術の確立



- Basic experiments on the data collection system (DCS)

MOS-1b is made by refurbishing the MOS-1 proto-type model and its mission objectives are as follows.

- Succession of earth observation by MOS-1
- Establishment of earth observation system operation technology including two satellite operations
- Establishment of refurbising technology

主要諸元

形状	一翼式太陽電池パドルを有する箱型 本体1.26×1.48×2.4(m) 太陽電池パドル2.0×5.28(m)	
重量	打上げ時　約740kg	
姿勢安定方式	三軸姿勢安定方式（コントロールドバイアスモーメンタム方式）	
ミッション期間	2年	
信頼度	2年後の残存確率　0.5以上	
打上げロケット	MOS-1：N-Ⅱロケット、MOS-1b：H-Ⅰロケット	
打上げ場所	種子島宇宙センター	
打上げ日時	MOS-1：昭和62年2月19日、MOS-1b：昭和64年度冬期	
軌道	種　類	太陽同期準回帰軌道
	高　度	約909km
	傾　斜　角	約99度
	周　期	約103分
	回帰周期	17日（西方移動）
	降交点通過 地方平均太陽時　午前10時～午前11時	

Major Characteristics

Shape	Box type with expanding one solar paddle (one wing) Body 1.26×1.48×2.4(m)　Solar paddle 2.0×5.28(m)	
Weight	Approx. 740kg (at lift off)	
Attitude Control	Three-axis stabilized (controlled bias momentum)	
Mission life	2 years	
Reliability	0.5 (after 2 year in orbit)	
Launch vehicle	MOS-1: N-II rocket, MOS-1b: H-I rocket	
Launch site	Tanegashima Space Center, Kagoshima	
Launch date	MOS-1: 10:23 a.m. February 19, 1987, MOS-1b: early 1990	
Orbit	Type	Sun Synchronous Subrecurrent
	Altitude	Approx. 909km
	Inclination	Approx. 99deg.
	Period	Approx. 103min.
	Recurrent period	17 days (west-ward shift)
	Descending Node Time 10:00~11:00 a.m.	

ミッション機器主要諸元

観測機器

観測機器	可視近赤外放射計（MESSR）	可視赤外放射計（VTIR）	マイクロ波放射計（MSR）
観測対象	陸域、海域	雲及び海面温度	海面、大気中の水蒸気、海氷、積雪
走査方式	電子走査（CCD利用）	機械走査	機械走査
観測波長帯域数	可視域2バンド 近赤外域2バンド	可視域1バンド 熱赤外域3バンド	23GHz帯、31GHz帯
分解能	約50m	可視域約900m 熱赤外域約2700m	23GHz帯:約32km 31GHz帯：約23km
観測幅	約100km （両系運用時約200km）	約1500km	約320km

Major Specifications of Mission Equipments

Measurement Equipment

Measurement Equipment	Multispectral Electronic Self Scanning Radiometer (MESSR)	Visible and Thermal Infrared Radiometer (VTIR)	Microwave Scanning Radiometer (MSR)
Measurement objectives	Air, Sea	Clouds, Temperature of ocean surface	Sea surface, Water vapor, Snowfall
Scanning method	Electronic (using CCD)	Mechanical	Mechanical
Wavelength, Frequency	Two visible bands, Two near-infrared bands	One visible band, Three thermal infrared bands	23GHz band, 31GHz band
Resolution	Approx. 50m	Visible range: 900m, Thermal infrared: 2700m	23GHz band: Approx.32 km, 31GHz band: Approx.23km
Swatch width area	Approx. 100km (Approx. 200km when both systems are operated)	Approx. 1500km	Approx. 320km

データ収集システム中継器

機能	データ中継プラットフォームからのデータの中継
方式	ランダムアクセス型位相再変調方式
使用周波数帯	400MHz帯（アップリンク）及び1.7GHz帯（ダウンリンク）

Transponders for Data Collection System

Function	Relay of data from data collection platform
Method	Random access phased remodulator
Operating frequency band	400MHz band (uplink) and 1.7GHz band (downlink)

可視近赤外放射計(MESSR)

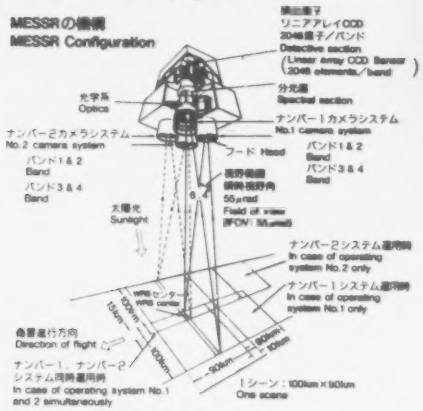
MESSRは、地表面の太陽反射光を捉える電子走査式の放射計で、衛星進行方向に並行して2系統のカメラシステムを装備しています。

Multi-spectrum Electronic Self-scanning Radiometer (MESSR)

MESSR is an electronic scanning radiation meter that collects solar light reflected the earth surface.

It is equipped with two camera systems that are set parallel to the satellite's flight direction.

MESSRの機構
MESSR Configuration



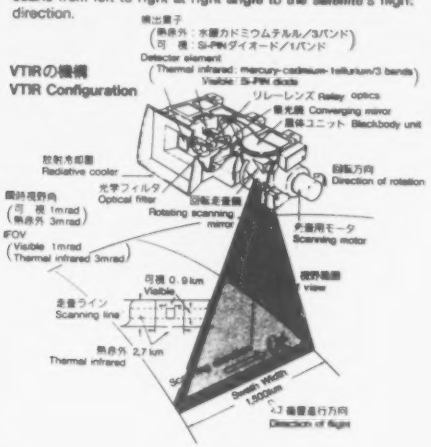
可視熱赤外放射計(VTIR)

VTIRは、回転する走査鏡により、衛星の進行方向に対して直角に、右から左へと機械的に走査します。

Visible and Thermal Infrared Radiometer (VTIR)

Using a rotating scanning mirror, the VTIR mechanically scans from left to right at right angle to the satellite's flight direction.

VTIRの機構
VTIR Configuration



MOS-1によるMESSR画像

(札幌市周辺：昭和62年4月27日　午前10時14分～22分)

The photo of MESSR image by MOS-1

(in and around Sapporo city: April 27, 1987, from 10:14:00 a.m. to 10:22:00 a.m. JST)

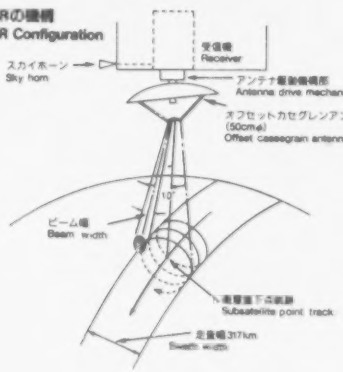
マイクロ波放射計(MSR)

MSRは、衛星に搭載したパラボラアンテナを回転させることにより、衛星の進行に沿って連続して地表を走査する電波センサーです。

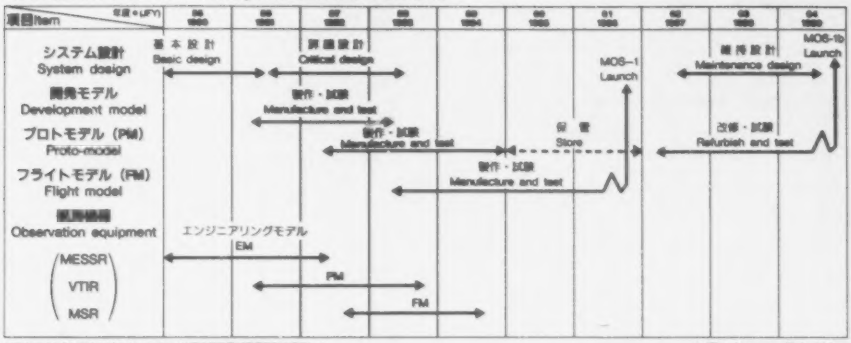
Microwave Scanning Radiometer (MSR)

The MSR is a signal sensor that rotates the dish antenna mounted on the satellite so that as the satellite moves over the earth surface, the sensor can continuously scan a path on the earth surface.

MSRの機構
MSR Configuration



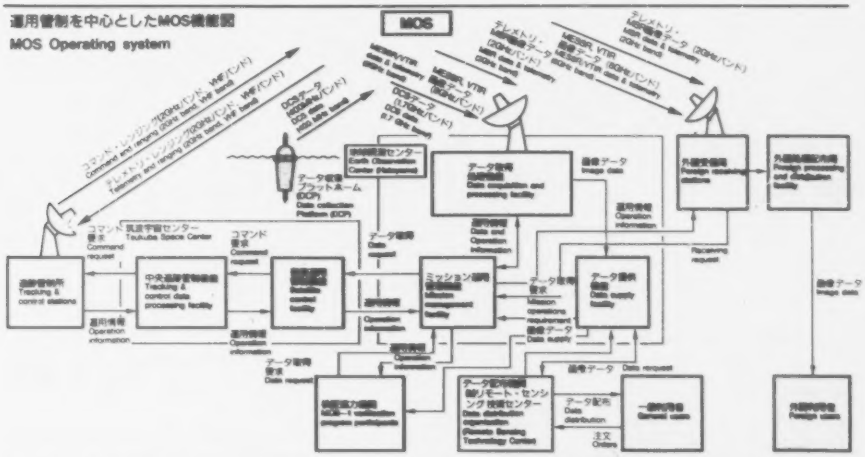
MOSの開発スケジュール　Development Schedule of the MOS



52年(1977)から54年(1979)にかけてMOS-1の概念設計及び予備設計を実施した。
Conceptual design and preliminary design for the MOS-1 were carried out from 1977 to 1979.

* JFY : Japanese Fiscal Year

運用管制を中心としたMOS機能図
MOS Operating system


MOS
コマンド・レンジング 2GHz帯 (Sバンド) S-band
テレメトリ・レンジング 2GHz帯 (Sバンド) S-band
MESSR, VTIR 観測データ 2GHz帯 (Sバンド) S-band
DCPデータ 402.65MHz帯 DCP data 402.65MHz band
DCPデータ 8.175GHz帯 DCP data 8.2 GHz band
地球観測センター Earth Observation Center Planned
データ収集プラットホーム (DCP) Data collection Platform (DCP)
筑波宇宙センター Tsukuba Space Center
コマンド要求 Command request
データ管理 Data management facility
データ要求 Data request
運用情報 Operation information
追跡管制所 Tracking & control stations
中央追跡管制局 Tracking & control data processing facility
ミッション運用 Mission management facility
データ供給 Data supply facility
ミッション要求 Mission operations requirement
観測データ Image data
受信要求 Receiving request
外国地球観測局 Foreign receiving stations
外国地球観測処理局 Foreign processing and distribution facility
MOS-1 calibration program participants
データ配布 Data distribution
一般利用者 General users
外国利用者 Foreign users
注文 Orders

利用

MOSにより得られる画像データは地球観測技術を確立するために行われる様々な利用実験のために、大学、研究所などの利用機関に提供されます。また外国からもこれらのデータの利用の引き合いが来ています。宇宙より地上を撮像して得た可視域、赤外域及びマイクロ波による画像データは、農林・水産資源、水資源の利用状況の調査、海洋・大気汚染等の監視などに利用できるものと期待されています。

Utilization of data

Picture data obtained from the MOS will be distributed to universities, research institutes and other user institutions so that they can perform many different kinds of experiments that will lead to the establishment of earth observation technology. Many foreign countries have requested the use of these data. It is anticipated that the visible, infrared and microwave image data taken from space are useful to monitor water and air pollution and to survey agricultual, marine and water resource use.

NASDA 宇宙開発事業団

●宇宙開発事業団
〒105 東京都港区浜松町2-4-1 世界貿易センタービル
TEL: 03-5470-4111 FAX: 03-433-0796
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN
World Trade Center Building
2-4-1, Hamamatsu-cho, Minato-ku Tokyo 105 Japan
Phone:81-3-5470-4111 FAX:81-3-433-0796
Telex:J26424(AAB:NASDA J26424)

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Mr. SCHEUER. Thank you very much, Mr. Tadakawa. Does Mr. Yamagami wish to testify?

Mr. TADAKAWA. No.

Mr. SCHEUER. Okay. Well, we've enjoyed the testimony very much.

Mr. Tadakawa, you say that you don't believe in the viability of commercialization and that at the present time it's not justified.

Mr. TADAKAWA. Yes.

Mr. SCHEUER. Even if the entire cost of satellite development and launch were excluded. Now on this there seems to be a difference of opinion.

The French believe it's viable. The Russians believe it's viable and the Americans believe it's viable.

You may turn out to be right. We don't know yet. The final result is not in.

Our science committee is going to visit Japan in August and I hope very much that we will have the chance to sit down and confer with you and Mr. Yamagami and other experts and other government authorities to discuss this matter further.

One obvious possibility is that we could join in an international consortium to develop the satellite and to absorb the cost of development and launch. That seems to be obvious—sharing our science and sharing the cost.

But then we get to some other tricky, thorny questions on commercialization. Who owns the data? If there are two or three or four countries involved in developing the capital cost of the satellite and the launch cost, then who owns the data? And if they all own it, how do we structure the competition? Do we carve up the planet and give each a certain share or do we let them compete each of them everywhere? These are some thorny and intellectually challenging questions that we ought to be engaged in examining.

In any event, I hope that we will have the chance to discuss many of the implications of a consortium on the development and launching of the satellite with the Japanese and the French and the Russians and when our science committee arrives in Japan I hope we will have the opportunity to continue this discussion with you.

I am now going to yield to the ranking member of the full Science Committee who's shown an enormous creative interest in this subject of satellite sensing, Congressman George Brown of California.

Mr. BROWN. Thank you, Mr. Chairman.

Mr. Julyan, you haven't given us too much information in your statement about the projected market that you perceive or the degree to which the system would be commercially profitable, assuming it had to absorb the cost of space segment and so forth.

Could you comment briefly on what you see the market being, say, for the year 2000? Have you seen the studies that were commissioned by the Department of Commerce on what the market would be?

Mr. JULYAN. Yes, Congressman, I've read them.

Mr. BROWN. All right. You can sort of indicate your own feelings about whether they're accurate or whether your own guess would be it's high or low or whatever.

Mr. JULYAN. Congressman, at this stage in the development of commercialized remote sensing, the two most significant current statistics that we watch—and this again is strictly from the perspective of a businessman—are both the total revenue that we're receiving every year and also the increase over the previous year.

The latter is not to be underestimated. At an early stage in a developing and commercialized industry, both the total revenue generated—I live and die by P&L pressure by my board of directors—as well as the growth that you can now estimate based on performance are the most significant indicators for us.

Today, what we are most pleased with that increase one year to the next. For each of the last three years, for example, SPOT increases have been well in excess of 60 percent. In the United States our revenues are running closer to 70 percent increase from one year to the next.

Where we think this will take us by the year 2000 is the following. The numbers that I would use would come from three different sources.

Last year the Department of Commerce Space Commercialization Office released a report that estimated that by the year 2000 or approximately that period total turnover for the industry from now to that time would be in the $6 to $7 billion range and that the turnover on an annual basis by the year 2000 would be approaching $1 to $1.5 billion a year.

We have to be careful with these numbers because we have to decide what we're counting. For us, we basically consider the remote sensing industry to consist of three components: the suppliers of data, SPOT, Landsat; the value-added firms who take that data and extract specific information from it and deliver that to customers; and the image processing computer manufacturers whose equipment and software is vital to the exploitation of the data.

If you take all of those components together, now you're looking at an industry that the Department of Commerce has estimated would be in that $1 to $2 billion range for annual sales.

Of the three studies that were done for the Department of Commerce last year, the study done by TASC and the study done by KRS estimated markets which were primarily based on just the data supplier and value-added components. They did not look—as I understand the studies, they did not look as closely into the system manufacturers, the image processing system manufacturers. And I would not disagree with the numbers in either one of those reports. I think they are a little conservative, but I think they are realistic.

Finally, for SPOT itself, our numbers would be a little higher. I don't have an exact number for you, Congressman Brown, but our numbers for the year 2000 for data suppliers worldwide, all data suppliers, would be just for raw data in the neighborhood of $100 million. The value-added component of the industry should be pegged at something like three to five times that amount. So we would certainly look at the industry, data supplier value-added and focus on that component, as something in the $5 to $7 hundred million range.

Mr. BROWN. Well, that's not too much different from the studies that were made.

Mr. JULYAN. No.

Mr. BROWN. Now given that figure, is it feasible to extract from that sufficient to pay for the space segment of a system? Is it your intention that SPOT, for example—you're not marketing based upon amortizing the cost of the space segment, are you?

Mr. JULYAN. The structure for SPOT is the following. We generate our revenues from the development of products and markets and the delivery to our customers. We emphasize in rather a strong and deliberate way the development of new commercial private sector customers rather than dependency on government use of our data.

The current structure for SPOT is that for every data set that we sell as SPOT Image we pay to the CNES, the owner-operator of the system, a royalty. That royalty today does not cover the cost associated with the space segment of the SPOT system.

It is our belief that in the future—and your turn-of- the-century number is a pretty good number—we will be generating sufficient royalties back to the CNES to handle the expenses of the space segment as well as the ground segment costs.

Mr. BROWN. Well, that's the kind of information I would like to see more detail on because I have a sneaking suspicion that unless you have used the most optimum projections that it would be difficult to do that.

Of course, this leads to a further exploration of the possibility that using the mechanism that you've suggested of royalties to defray the cost of the space segment, that the space segment could be initially financed by some sort of an international consortium which would draw from all the products, and then the marketing of the product would be strictly a private sector operation in which every effort could be made to fully develop and exploit to the maximum whatever markets exist. I'm sorry I won't have time to explore that, but that's the direction of thinking that I would like to see explored and I presume is being explored by your discussion between NOAA and SPOT.

Mr. JULYAN. If I could make just two brief comments, Congressman. First, I couldn't agree with you more that the development of the market and the handling of the data once the data are on the ground must be handled by private companies. Anything else and we will have a continuation of a changing equilibrium between public and private sector responsibility for these types of programs. Clear role identification between the public and private entities is crucial. That's been true for SPOT from the beginning and I would argue one of the key elements to our success thus far.

The other comment I would make is that, while obviously covering the financial responsibilities of a space segment such as remote sensing is always important, it's also important to note that remote sensing systems, in addition to their commercial goals, have other responsibilities and goals which are being met.

In the case of the SPOT program, for example, there are technical, industrial, political and international goals in addition to our commercial goals which are being met. The commercial goals always dominate and have the highest priority, but we are not ignorant of nor do we ignore the impact of these other factors in our operation.

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So when we start talking about recovering space segment costs, while, yes, we always look to the bottom line, we also have to recognize, especially during this period of transition, that the other goals of remote sensing programs, goals of the public good, also have value.

Mr. BROWN. There's no question about that and I hope very much that in your discussions with NOAA you can reach some common ground of understanding of what the appropriate apportionment of cost between the commercial aspects and the non-commercial aspects are. I think the United States has been derelict in not having policies which fully reflected the distinctions that you apparently make.

Thank you, Mr. Chairman.

Mr. SCHEUER. Thank you.

Now I'd like to recognize Chris Shays of Connecticut. Chris, why don't you take about six or seven minutes.

Mr. SHAYS. Mr. Chairman, I'll actually only need about one minute.

First, on behalf of Congresswoman Claudine Schneider, I request unanimous consent that the University of Rhode Island which is sending her documents be allowed to submit their documents discussing the importance of Landsat, with your permission.

Mr. SCHEUER. Without objection, so ordered.

[The material referred to follows.]

The University of Rhode Island, Kingston, RI 02881-0804
Natural Resources Science, College of Resource Development (401) 792-2495

May 5, 1989

The Honorable Claudine Schneider
U.S. House of Representatives
30 Rolfe Road
Cranston, RI 02910

Dear Representative Schneider:

Thank you for responding to my letter regarding the status of Landsats 4 and 5. I was happy to hear that one of our Rhode Island Congressional Representatives is a strong supporter of the Landsat program.

As you know, Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) are installed on both Landsats 4 and 5. The data collected by these satellite platforms are valuable to natural resource investigators throughout the world. To this point in time, Landsat data have been useful in small scale resource inventories such as land use and land cover classification and change detection, identification and delineation of wetlands, detection of vegetation stress resulting from acid rain, drought, insects and disease, and also in coastal remote bathymetry applications, just to name a few. Here in Rhode Island, we are working to integrate satellite remote sensing imagery with our state-wide Geographic Information System (GIS) data to facilitate the development and update of our data base.

In comparison with foreign remote sensing satellite products (*e.g.*, SPOT), TM offers increased radiation detection sensitivity as well as more spectral bands. Landsats 4 and 5 are presently in orbit, operational and ground receiving stations for data are already in place. I believe the operating costs are now generally constrained to terrestrial management, processing and data distribution. If the program is abandoned after committing such a substantial investment, it would be a loss to many.

I have enclosed evidence of my use of Landsat data in the form of a technical paper that I presented last month in Baltimore, MD at the American Society for Photogrammetry and Remote Sensing convention. This paper describes a land

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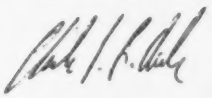
use and land cover classification study that was performed using Landsat TM data for a portion of Connecticut. Many other papers describing various applications of Landsat remote sensing data are available through the published proceedings of this conference. I hope that this will assist your efforts to keep the program going. Thanks again for your attention to the Landsat issue.

Sincerely,



Charles L. LaBash

RIGIS Data Base Manager

THE USE OF LINEARLY TRANSFORMED LANDSAT THEMATIC MAPPER DATA IN LAND USE AND LAND COVER CLASSIFICATION

Charles L. LaBash, Database Manager
Environmental Data Center
Department of Natural Resources Science
The University of Rhode Island
210-B Woodward Hall
Kingston, RI 02881

Daniel L. Civco, Assistant Director
William C. Kennard, Director
Laboratory for Remote Sensing
Department of Natural Resource Management and Engineering
The University of Connecticut
U-87, Room 308, 1376 Storrs Road
Storrs, CT 06268

ABSTRACT

TM digital image data acquired on June 9, 1986 and March 24, 1987 were subset and atmospherically corrected for a 512 × 512 pixel subscene centered around the town of Mansfield, CT. Linear transformations, band ratioing, principal components analysis and the tasseled cap transformation, were applied to the original data to produce eight transformed images. Training areas were selected from each of the transformed and non-transformed images. A supervised classification into 17 detailed land use and land cover classes was performed. Each of the nine classified maps was aggregated into ten somewhat general and seven very general classes and then geo-referenced to Universal Transverse Mercator (UTM) coordinates. Accuracy was assessed by digitizing ground truth test polygons and performing a pixel-by-pixel comparison with each of the 27 classification maps. Percentage agreement with ground truth data as well as errors of omission and commission were recorded and analyzed.

The detailed class of cropland was well represented by the tasseled cap classification map with an agreement of 71.8 percent. Deciduous forest with a southeastern exposure was classified with an 88.9 percent agreement using using the principal components image. Deciduous forest western aspect was somewhat lower with an agreement percentage of 55.0. Combining the two deciduous forest categories yielded an agreement of 83.3 percent from a ratio-composite image. The general category of water was represented quite accurately in all nine classifications with the highest agreement of 95.7 percent coming from a multitemporal near infrared and middle infrared over red ratio. Several of the classifications were somewhat marginal with respect to the nontransformed data whereas others produced a notable improvement over the original data. The results enable the selection of the appropriate band combinations and transformations to maximize classification accuracy for select categories.

INTRODUCTION

Many investigations have already been conducted using satellite data to classify land use and land cover. For example, Hill and Megier (1986) performed a digital classification of the Ardeche region of Southern France using Landsat 5 Thematic Mapper (TM) data as part of a region-wide resource inventory being conducted by the French government. Trolier and Phillipson (1986) performed both a visual and digital analysis of TM data in New York to classify hydrologically important land use

and cover types for eventual input into a watershed runoff model. Khorram *et al.* (1987) evaluated Landsat Multispectral Scanner (MSS) and TM data for an urban land use classification study in North Carolina hoping to provide urban planners with information that would allow them to develop extended management plans for sewage, water and transportation networks. Other urban and suburban land use and land cover studies were performed by Toll (1984) using simulated TM and actual MSS data in Colorado as well as by Ioka and Koda (1986) using TM in Japan. Pettinger (1982) performed a comprehensive digital classification of vegetation and land cover in Idaho producing several maps at different levels of detail for natural resource management purposes. Scientists at the University of Connecticut Laboratory for Remote Sensing (LRS) have studied the utility of deriving land use and land cover information in Connecticut from MSS and TM data as part of an ongoing project to develop an integrated land use planning system (Civco and Honkala, 1984; Civco, 1987; Callahan, 1986; Callahan, 1988).

There are characteristics inherent in Landsat data which introduce problems to conventional digital image classification. For instance, a single TM scene contains approximately 231×10^6 pixels with eight bits of data stored for each pixel, resulting in a large and complex data set. This hinders the efficient extraction of features contained in the data and causes machine processing problems in terms of storage, analysis and data display (Merembeck and Borden, 1978; Crist and Kauth, 1986; Merembeck and Turner, 1980). Aside from the complexity of the data, there also exists a high degree of redundancy (Blodget *et al.*, 1978). Analysis of the correlation matrices of a seven-band TM image shows a high correlation among visible Bands 1, 2 and 3 and reflective infrared Bands 4, 5 and 7 (Lauer *et al.*, 1985; Trolier, 1986). Researchers have attempted to reduce the redundancy and complexity of Landsat data by selecting a subset of optimal TM band combinations for land cover classification and other applications which serve to reduce processing costs while preserving accuracy and reliability (Gervin *et al.*, 1985). Choosing a set of optimal features or bands in a multispectral data set which provides the highest degree of separation among classes is referred to as feature selection, this being one form of feature reduction (Richards, 1986).

One way to accomplish feature reduction is to transform the multispectral data set using a variety of linear arithmetic and statistical transformations such as simple ratios of multispectral bands and more complex transformations based on statistical rotations of the original data axes. The resulting transformed data set will have a reduced set of features which contain nearly as much of the total information content as the original data. Some of the more commonly used linear transformations, such as band ratios, vegetation indices, principal components analysis, and tasseled cap transformation, generally serve to reduce the redundancy and complexity of the data so as to lessen processing costs and storage space as well as to increase data interpretability (Lodwick, 1979; Crist and Cicone, 1984a; Merembeck and Borden, 1978). Along with reducing the redundancy and complexity of a multispectral data set, certain linear transformations also help to normalize the effects of natural scene class variation such as that caused by atmospheric attenuation and shadowing (Rouse *et al.*, 1973; Justice *et al.*, 1981). Other transformations have been found to be effective in isolating specific cover types such as soils and vegetation for use in agricultural biomass studies (Rouse *et al.*, 1973; Kauth and Thomas, 1976). Most research employing linear transformations has been performed using multispectral data collected from homogenous agricultural areas for use in crop identification and monitoring (Pech and Graetz, 1986). The degree to which these insights may be applied in the analysis of heterogeneous landscapes has been explored very little (Goward, 1984).

PROCEDURES

The Study Area

The study area chosen for this research spans portions of five United States Geological Survey (USGS) topographic quadrangles (Coventry, Spring Hill, Hampton, Columbia and Willimantic) and seven towns (Willington, Mansfield, Ashford, Chaplin, Coventry, Columbia, and Windham) covering an area of 17,960 hectares (44,370 acres). The study area is centered around Spring Hill in Mansfield, Connecticut. The region is influenced by a temperate New England coastal climate and characterized by an undulating topography consisting of a variety of diverse land use and land cover types. Deciduous hardwood forest is the dominant land cover with areas of coniferous forest, forested and non-forested wetlands, as well as lakes, ponds rivers and streams.

For this multitemporal land use and land cover classification experiment, two recent Landsat TM images from Path 12/Row 31 were selected. The first scene was scanned on June 9, 1986 and the second on March 24, 1987. Both scenes were chosen based on their temporal differences at the times of the Landsat overpass. During the March 1987 overpass, deciduous vegetation was still dormant allowing for the detection of physical features which would otherwise be indistinguishable in a full forest-canopy-closure condition. Also during this time, many of the lakes and ponds in the scene were still partially covered with ice allowing for a multitemporal comparison with water that was free of ice in the June scene. At the time of the June 1986 acquisition, much of the deciduous vegetation was approaching full leaf and crops were in a stage of early emergence. The seasonal differences between the two scenes were sufficient enough so that they could be combined for multitemporal analysis to aid in the discrimination between land use and land cover types.

Image Preprocessing

A 512 x 512 pixel study area was subset from both the June 1986 and March 1987 scenes consisting of Bands 1 through 5 and 7. Band 6, the thermal infrared band, was not extracted from either of the two images because of its lower spatial resolution – 120 meters versus that of 30 meters for the other bands. Because of this and other problems such as providing a low contrast in forested areas, other researchers have also chosen to omit the thermal band from their land cover classification experiments (Horler and Ahern, 1986; Khorram *et al.*, 1987). Ten control points were selected for corresponding areas on both images and an image-to-image registration was performed using a nearest neighbor resampling technique to register the March image to the June image with a residual mean square error of 0.85 pixels. Both images were then combined to form a 12-band multitemporal data set.

An atmospheric correction was applied to normalize reflectance variation between the two images attributable to atmospheric differences at the time of aquisition. The technique used in this research bears resemblance to the radiometric calibration used by Lo *et al.* (1986) and Volchok and Schott (1986). They describe normalization with respect to features with invariant reflectance through time and illumination angle known as *psuedo-invariant* features (*e.g.*, airport runways, asphalt, concrete and water). Since many of the transformations used in this research have been shown to normalize certain radiometric effects, a minimal radiometric correction was desired so as not to interfere with or confound any discriminatory information contained in these raw data that might be enhanced through transformation. The entire distribution of reflectance values was shifted

according to the difference between the lowest digital number in each of the corresponding multitemporal band pairs.

Band Reduction

The original intent of this research was to transform and classify the entire twelve band multitemporal image. However, it was discovered that the ERDAS(ERDAS, 1987) software used in these studies only accommodates a maximum of eight bands in a maximum likelihood classification and principal components transformation. For this reason, the number of original bands had to be reduced to eight. In order to determine the optimal eight-band subset to be selected from both images, a principal components transformation was run on each of the 6-band March 1987 and June 1986 subscenes using the **ERDAS** program **PRINCE**. Because approximately 95 and 97 percent of the total spectral variation was accounted for in the first and second principal components for both the March and June scenes, these components were relied upon when the loading of bands in the eigenvectors was examined to determine the optimum eight-band subset. The eigenvector loadings for the first (**PC1**) and second (**PC2**) principal components were ranked separately in descending order starting with the highest absolute value of the eigenvector in each component. The higher the rank the better the indication that a particular band was contributing significantly to the total discriminatory variance in the image. Bands 1, 3, 4 and 5 were selected. In support of the Bands 1, 3, 4 and 5 subset, other researchers have found this TM band combination to be ideal for land cover classification because it provided one band in each major region of the spectrum (visible, near and middle infrared) (Gervin *et al.*, 1985). Trolier *et al* (1986) found TM bands 3, 4 and 5 to provide maximum separability in a hydrologic land use and land cover classification experiment.

The bands in the radiometrically corrected and registered multidate image **MULTIRAD** (1, 3, 4, 5, 7, 9, 10 and 11), corresponding to Landsat TM bands 1, 3, 4, 5 from both dates, were subset to form Bands 1 through 8 in a new image called **MR8**. This new image consisted of a reduced set of optimum bands from the June and March scenes that were registered to one another and radiometrically corrected.

Linear Transformations

Even though the number of bands had to be reduced from twelve to eight in order to perform a maximum likelihood classification and principal components analysis, there were other transformations which could be performed using all twelve bands that would reduce the dimensionality to a number of eight or less, thus making it possible to classify the resulting transformed images. This was accomplished with both band ratioing and the tasseled cap transformation.

There were five ratioed images produced from the 12-band multidate image **MULTIRAD**. There are 66 different pair-wise ratios that can be generated using twelve bands (132 when the inverse ratios are included). When these ratios are combined in groups of eight the number of different combinations becomes quite large. For this reason, most of the ratio combinations selected were based on those used in previous research (Tucker, 1979; Miller, 1976; Blodget *et al.*, 1978; Pinter *et al.*, 1987; Maxwell, 1976). All of the composite-ratio images were generated using the **ERDAS** program **DRATIO**. Because ratioing greatly reduces image contrast, a scaling parameter was applied to each of the resulting output images in order to stretch the brightness values over a larger range. This contrast enhancement greatly improved the visual separability of features in the ratioed images.

The first transformed image was derived from the 12-band multidate image **MULTIRAD**. Each of the reflective values from bands 1 through 6 for the June 1986 scene were divided by values for those same bands from the March 1987 scene to create a six-band ratio composite named **MRAT**.

The second ratioed image was produced by ratioing **MULTIRAD** bands corresponding to TM bands:

$$June\ \frac{4_{(NIR)}}{3_{(RED)}}, March\ \frac{4_{(NIR)}}{3_{(RED)}}, June\ \frac{5_{(MIR1)}}{3_{(RED)}}, and\ March\ \frac{5_{(MIR1)}}{3_{(RED)}}$$

to produce a four-band image called **WIR4**. This is a multitemporal intradate near-infrared over red (NIR/RED) and middle-infrared over red (MIR/RED) image which should enhance green vegetation that has a typically high reflectance in the near (Band 4) and middle (Band 5) infrared portions of the electromagnetic spectrum. Green vegetation has a typically low reflectance in the red (Band 3) due to high chlorophyll absorption so that the ratio of the infrared to the red will result in a high numerical value being assigned to green vegetation classes. This NIR/RED ratio or vegetation index has been successfully used by other scientists to enhance vegetation using Landsat MSS (Tucker, 1979; Maxwell, 1976). Holben and Justice (1981) also found that intradate ratioing reduces the effect of differential illumination due to topographic variations in the landscape.

The third transformed image is also a ratio-composite of the **MULTIRAD** image and was produced by ratioing bands corresponding to TM bands:

$$June\ \frac{4_{(NIR)}}{3_{(RED)}}, March\ \frac{4_{(NIR)}}{3_{(RED)}}, \frac{March\ 4_{(NIR)}}{June\ 3_{(RED)}}, and\ \frac{June\ 4_{(NIR)}}{March\ 3_{(RED)}}$$

creating a new four-band image called **BWIR4**. This image is made up entirely of NIR/RED ratios; however, instead of being just intradate ratios as in **WIR4**, the ratios are both interdate and intradate. The rationale for the intradate IR/RED ratios has been discussed in the previous paragraph. The rationale for interdate ratios was also discussed in the formation of **MRAT**, but not in the context of the IR/RED ratios. The interdate IR/RED ratio may provide an extra degree of normalization for radiometric differences between the two dates as well as enhance vegetation.

The fourth image, **BWIR3**, is a composite-ratio of **MULTIRAD** bands corresponding to TM bands:

$$June\ \frac{4_{(NIR)}}{3_{(RED)}}, March\ \frac{4_{(NIR)}}{3_{(RED)}}, and\ \frac{March\ 4_{(NIR)}}{June\ 3_{(RED)}}$$

This image is very similar to **BWIR4** except the last ratio was excluded to test the performance of a three-feature ratio composite as well as to see what the effect of leaving out the last ratio would have on classification results.

The fifth transformed image was created by ratioing **MULTIRAD** bands corresponding to June TM bands:

$$\frac{3_{(RED)}}{1_{(BLUE)}}, \frac{5_{(MIR1)}}{4_{(NIR)}}, \frac{5_{(MIR1)}}{7_{(MIR2)}}, and\ March\ TM\ bands\ \frac{3_{(RED)}}{1_{(BLUE)}}, \frac{5_{(MIR1)}}{4_{(NIR)}}, and\ \frac{5_{(MIR1)}}{7_{(MIR2)}}$$

to form a six-band multidate-intradate ratio-composite called **ARAT**. The rationale behind using this combination of ratios is not as clearly defined as were the ratio-composites generated previously. Most of the ratios in this composite included the infrared bands from both dates. Blodget *et al.* (1978) has used the MSS IR/IR ratio

$\frac{6}{7}$ along with other ratios in rock discrimination studies. However, most experiments with ratios have involved dividing the visible by the infrared bands to enhance vegetation and little emphasis has been placed on accentuating different cover types with ratio combinations obtained from other spectral regions such as the middle and far-infrared as well as the blue visible band. It was hoped that this combination would improve the classification of cover types not enhanced by the IR/RED ratios.

The sixth transformed image, **MP8**, was created by applying a principal components transformation to the 8-bands of **MR8** producing an output image of eight uncorrelated principal components which contained a majority of the spectral variation in the first two or three axes.

The seventh transformed image, **PCMR**, was created by running a principal components analysis on **MRAT**, the six-band image that was transformed through interdate ratioing of **MULTIRAD**. The ratioing will hopefully reduce radiometric variations associated with the atmosphere, sun angle, and sensor while the principal components transformation will condense most of the total discriminatory variation into fewer than six axis or principal components.

The eighth and last transformed image, **MCAP** was created by subjecting **MULTIRAD** to the tasseled cap transformation. Crist *et al.* (1986) developed for Landsat-5 TM a matrix of coefficients along with a vector of additive terms used to obtain the signal range equivalence of the previously derived Landsat-4 TM tasseled cap. This matrix of coefficients and vector of additive terms was applied to Bands 1 through 6 and repeated for bands 7 through 12 of the 12-band multitemporal image **MULTIRAD** using the **ERDAS** program **DLNCOM**. The result was a 12-feature TM tasseled cap image made up of separate transformations of both the March 1987 and June 1986 bands. Because of **ERDAS's** eight-band limitation in its implementation of the maximum likelihood classifier, the first four features from June (1, 2, 3, and 4) and March (7, 8, 9, and 10) were combined into an eight-band tasseled cap image. This image contains a majority of the important physical scene class variation from both the June and March images in the eight TM tasseled cap features.

Training Area Selection

Prior to the selection of training areas that were to be input into a supervised maximum likelihood classifier, the nine images were run through an unsupervised classifier using the **ERDAS** program **CLUSTR** to determine the grouping of pixel values within the scene.

Using the modified Anderson *et al.* (1976) Connecticut Land Use and Land Cover Classification System and the spectral cluster characteristics of the scene as a guide, a set 17 combined Level 3, 2 and 1 (referred to in this paper as Level 3.2.1) categories were chosen as classes for supervised training. These Level 3.2.1 classes are shown in the following modified classification hierarchy:

Level 1	Level 2.1	Level 3.2.1
1. Urban	1. Residential	1. High density residential
		2. Medium density residential
		3. Low density residential
	2. Commercial	4. High impervious cover
		5. Medium impervious cover
		6. Low impervious cover

2. Agriculture	3. Cropland/pasture	7. Cropland 8. Pasture
3. Rangeland	4. Rangeland	9. Rangeland
4. Forest	5. Deciduous forest	10. Deciduous forest SW aspect 11. Deciduous forest W aspect
	6. Coniferous forest	12. Coniferous forest
5. Water	7. Water	13. Water
6.Wetland	8. Forested wetland	14. Deciduous forested wetland 15. Coniferous forested wetland
	9. Non-forested wetland	16. Non-forested wetland
7. Barren	10. Barren	17. Barren

Training areas for the 17 classes were interactively selected from the display monitor. Four to five five different training polygons dispersed throughout the entire scene were selected for each of the 17 categories except for the non-forested and coniferous forested wetland categories which had only two and three polygons selected, respectively.

The training areas were identified through extensive photointerpretation of 1:12,000 low-altitude black and white aerial photographs acquired in 1986 covering the entire study area. A NHAP approximately 1:24,000 scale color infrared aerial photograph covering the western portion of the study area was also used as were the USGS 7.5 minute topographic maps. When there were doubts about the identity of a particular training area, a site visit was performed to check the original interpretation.

Approximately 1.3 percent of the 512 x 512 pixel study area was sampled for training with a total of 80 polygons made up of 3473 pixels from 17 combined Level 3.2.1 categories. The 80 polygons were used as a template in conjunction with the **ERDAS** program **DIGFIELD** to extract data values and calculate separate training statistics (spectral signatures consisting of the mean and standard deviation) for each polygon from each of the nine images to be classified. Each signature file corresponding to one of the nine images was then processed separately by aggregating the 80 signatures into 17 signatures corresponding to the 17 Level 3.2.1 categories using the **ERDAS** program **ADDSIG**.

Digital Classification

The signatures for each image were input into a maximum likelihood classifier (**ERDAS MAXCLAS**). Nine classified images were generated with the suffix **MAX** (for maximum likelihood) added to the names to distinguish them from the non-classified images.

Accuracy Assessment

In order to evaluate the performance of each of the eight transformed and one non-transformed images, an accuracy assessment was performed whereby test areas of known reference data were compared on a pixel-by-pixel basis with the same areas on each Level 3.2.1 classification map. In order to avoid bias, none of

the polygons corresponding to the training samples were used or overlapped by the test areas.

The test areas were selected using the **ERDAS** program **DIGSCRN** which allows data file coordinates for polygons to be digitized directly from the monitor using a joystick and cursor. Selecting test areas was almost identical to selecting training areas in that extensive use of ancillary information (*i.e.*, low and high altitude aerial photographs, topographic maps and ground verification) was required to ensure that the test areas were identified correctly. Effort was taken to select test polygons that were evenly distributed throughout the entire study area.

Using the **RECODE** operation of the **ERDAS** software, 77 test areas were assigned a thematic value of 1 through 17 corresponding to one of the 17 Level 3.2.1 categories used in this study. The resulting test area file was then overlayed each of the nine classified maps and a pixel-by-pixel comparison was performed using the **ERDAS** program **SUMMARY**. The program reported the number of ground truth pixels that were correctly classified for a given class as well as the number and class that the remaining pixels were falsely committed to. These Level 3.2.1 classification data were then restructured to form contingency error matrices for each classified map showing row-column totals, percent agreement by class, overall mapping accuracy, as well as errors of omission and commission for each class.

The techniques for calculating errors of omission and commission were obtained from Short (1982). An error of omission in the context of this study is failure to classify a pixel into the class to which it belongs. An error of commission is the erroneous inclusion of a pixel into a class to which it does not belong. The contingency tables were set up with the rows indicating the number of TM pixels that were classified into each category by class; the columns display which classes the ground truth pixels were included into by category. Errors of commission were calculated for each row-category by summing all the entries in a row and subtracting the number of pixels that were correctly classified for that category. Errors of omission were computed for each column-category by summing all the entries in a column and subtracting the number of pixels correctly included into that category. Percent omission and commission were calculated by dividing the omissions and commissions for each category by the truth class total for that category. The percent agreement by class was determined by dividing the number of correctly classified pixels for each class by the truth class total for that class. The overall mapping accuracy was obtained by adding the number of correctly classified pixels in each class and dividing by the sum of the truth class pixels.

The classifications were then evaluated at Level 2.1 by using the **ERDAS** program **RECODE** to renumber the 17 classes from the test area map and each of the nine Level 3.2.1 classification maps into ten Level 2.1 classes. The **ERDAS** program **SUMMARY** was used once again to perform a pixel-by-pixel comparison between the each of the Level 2.1 classification maps and the Level 2.1 test areas. Nine Level 2.1 contingency tables were constructed using the same procedure that was used to create the Level 3.2.1 tables.

The ten Level 2.1 classes were then aggregated into seven Level 1 categories using the same procedure outlined in the preceding paragraph. An accuracy assessment was performed by renumbering the Level 2.1 classification maps and Level 2.1 test areas into their corresponding Level 1 classes and performing a pixel-by-pixel comparison. Level 1 contingency tables were constructed for each of the nine classified images.

Geometric Correction

Because geometric rectification of Landsat data involves spatial resampling of pixel brightness values, this correction was performed as a final step in this study so that the spectral purity of the original data would be preserved for application of the linear transformations.

A series of twenty-one control points that were identifiable with a high degree of analyst confidence on both the 8-band raw image **MR8** and the corresponding USGS topographic maps were selected using the **ERDAS** program **GCP**. The (X,Y) data file coordinates from the image were recorded for each of the twenty-one points. The corresponding Universal Transverse Mercator (UTM) easting and northing coordinates were interpolated from the topographic maps. Both the image and map coordinates were input into the **ERDAS** program **COORD2** which calculated an affine transformation matrix based on a first order polynomial obtained through a least squares fit to the control points. A maximum RMSE of 1.0 pixel was defined prior to the calculation of the transformation matrix that resulted in the rejection of four of the control point pairs after several iterations of the program. The error contributed by these four control points introduced a total error exceeding the 1.0 pixel RMSE criterion. The final matrix based on seventeen control points was applied to each of the nine classified maps using the **ERDAS** program **RECTIFY**. This program performed the stretching and shrinking necessary to reference each of the nine maps to the UTM coordinate system. A nearest neighbor algorithm was used to resample the digital thematic values of the input image by selecting the pixel nearest to the floating point of the new UTM projection. Each of the nine maps was geo-referenced to sub-pixel accuracy with an X-RMSE of 0.88 and a Y-RMSE of 0.46 for a total RMSE of 0.99 pixel.

Classification Map Generation

Level 1, Level 2.1 and 3.2.1 land use and land cover thematic maps were generated for each of the nine classified images for a total of twenty-seven maps. Color schemes for the maps were based on those adopted by Connecticut and the USGS for land use and land cover map products (Anderson *et al.*, 1976; Avery and Berlin, 1985). Minor modifications in color tone were made in order to obtain the highest possible contrast between cover classes.

A color scheme was developed for the Level 3.2.1 classification maps by assigning a different color or color tone to each of the seventeen class values corresponding to the seventeen land use and land cover classes.

A Level 2.1 classification scheme was developed by assigning the same color to each group of Level 3.2.1 classes that was to be aggregated into a single Level 2.1 class. The Level 2.1 color scheme was then applied to each of the Level 3.2.1 maps using **GETCLR**. The same procedure was followed to generate the Level 1 classification maps.

DISCUSSION

At Level 3.2.1, the high density residential class was best classified in **MCAPMAX** with 44.2 percent agreement at the expense of a high (51.4) percent commission of other residential and commercial classes into high density residential. Medium density residential was best represented by **ARATMAX**, but with a low agreement of 28.2 percent and a large commission error of 77.6 percent. This map was more reliable than **MP8MAX** which had the highest percent agreement (37.6) but a correspondingly inflated commission error of 110 percent. Low density residential was well represented in terms of percent agreement by **MCAPMAX** (61.8); however, an

extremely high commission error of 189 percent forced the consideration of the **MR8MAX** classification map which had far fewer commissions at the expense of a lower percent agreement (32.6). This poor classification of urban classes at Level 3.2.1 suggests an aggregation of these detailed classes into more general categories. An increasing percent agreement and decreasing percent commission were observed when the detailed Level 3.2.1 urban classes were combined into more general residential and commercial categories at Level 2.1 and finally into the broader Level 1 urban category.

MCAPMAX provided the best overall percent agreement of 71.8 for the Level 3.2.1 cropland class with a commission error of 36.6 percent. Pasture was most reliably classified with a percent agreement of 54.7 by both **MR8MAX** and **MP8MAX** and a relatively low commission error of 48.3 percent. These maps were also most reliable for the cropland/pasture class at Level 2.1 with agreement of approximately 58 percent and a commission error close to 20 percent for both maps. Confusion of the agriculture class at Level 1 occurred mostly with urban and rangeland categories.

Rangeland was poorly represented on all maps because of the high inclusion of non-rangeland pixels into this category. The highest agreement for rangeland was 40.5 percent from **ARATMAX** with a commission rate of 156.5 percent, however. Deciduous forest southeastern aspect was classified with a high percent agreement in all maps with **MR8MAX** and **MP8MAX** providing the most reliable representations of this category with agreements of 88.9 percent and commission errors of approximately 23 percent. Deciduous forest western aspect was also most reliably represented by **MR8MAX** and **MP8MAX** with agreements of approximately 55 percent and low commission errors. As a whole, the deciduous forest class at Level 2.1 was classified with a high agreement (83.3 percent) and a low commission error (18.2 percent) in the **WIR4MAX** map. **BWIR4MAX** provided a good representation of coniferous forest at all levels with a percent agreement of 68.7 and a moderate commission error of 31.0 percent. As a whole, the forest category at Level 1 was best represented by **WIR4MAX** which had an agreement percentage of 77.1 and a commission error of 23.4 percent.

The percent agreement for the water category was very high in all nine classifications. **WIR4MAX** provided the best representation of water with an agreement of 95.7 percent with reference data and 0.0 percent commission from other classes. Deciduous forested wetland was marginally best represented by **BWIR3MAX** with a percent agreement of 61.6 and and a slightly less than average commission error of 41.6 in comparison with the other classifications. Coniferous forested wetland was best represented by both **MR8MAX** and **MP8MAX** with percent agreements of 72.9 and a high commission error of approximately 55 percent originating mainly from coniferous forest. Forested wetland at Level 2.1 was best classified by **MR8MAX** with a percent agreement of 64.7 and a commission rate of 44.5 percent. Non-forested wetland was very poorly classified by all of the maps with the highest percent agreement of 18.2 turned in by **ARATMAX**. The Level 1 wetland category as a whole was best represented by **MR8MAX** with a percent agreement of 56.7 and the second lowest commission of 39.6 percent.

The barren land category was best represented at all levels of classification by **MR8MAX**. Percent agreement was 71.5 and the percent commission was the second lowest for this category at 49.1. Cross-confusion was greatest between barren land and the urban and agricultural classes at Level 1.

It is evident from these results that no single image was instrumental in producing the best representation of every class at all three levels of classification. Certain

images were better suited than others in providing the most reliable classifications for different classes at different levels. At Level 3.2.1, **MR8MAX** and **MP8MAX** were very close to one another in several instances in providing relatively more reliable classifications of low density residential, medium and low impervious cover, pasture, deciduous forest southeastern and western aspect, and coniferous and nonforested wetland. At Level 2.1 these same maps were most reliable for classifying residential, cropland/pasture, and forested and non-forested wetland. As well, these two maps provided the most reliable classifications of urban, agriculture and wetland at Level 1. Barren land was best classified by **MR8MAX** at all three levels. **PCMRMAX** and **MRATMAX** provided poor classification of most classes. **BWIR3MAX** was marginal in producing the most reliable classification of deciduous forested wetland at Level 3.2.1 and not very reliable elsewhere. **BWIR4MAX** provided the best classification of coniferous forest at Levels 3.2.1 and 2.1, but also produced relatively poor classifications for other classes. The near-infrared over red ratio-composites, **BWIR3MAX** and **BWIR4MAX** were not well suited for classifying urban categories. **WIR4MAX** was most reliable in classifying high impervious cover at Level 3.2.1, deciduous forest at Level 2.1 and forest at Level 1. This map also represented water most accurately at all levels. Overall, **ARATMAX** provided better representations of many of the classes than the other ratio-composites. **MCAPMAX** provided the best representations of high density residential and cropland at Level 3.2.1.

CONCLUSIONS

In summary, the following conclusions are reached:

1. No single image produced the most reliable classification of each land use and land cover category at all three levels of classification. However, certain linear transformations were instrumental in producing more reliable classifications of specific categories.
2. In terms of overall reliability, the non-transformed image and the principal components transformation of this image produced the best overall mapping accuracy generally coupled with the lowest commission errors at all three levels of classification when classified with a per-pixel maximimum likelihood algorithm.
3. Ratios involving the NIR/RED bands were better suited for enhancing vegetated features (*e.g.*, forest) than they were for classes containing little or no vegetation (*e.g.*, urban).
4. The interdate ratio-composite **MRAT** and the principal component image (**PCMR**) of this composite produced rather poor representations of most categories at all levels as did the ratio composite consisting of three interdate and intradate NIR/RED ratios **BWIR3**.
5. Generally, classification at Level 3.2.1 was poor for most categories with a high incidence of errors of omission and commission. Classification reliability improved as classes were aggregated into more general levels of classification.
6. At Level 3.2.1, classification reliability was very good for water and deciduous forest southeastern aspect.
7. At Level 2.1, classification reliability was very good for water and good for deciduous forest.
8. At Level 1, classification reliability was very good for urban and water and good for the forest category.
9. Categorization of land use classes based on cultural land use designation (*e.g.*, high density residential) appears to create confusion when attempting to classify satellite radiance data with respect to the spectral signatures derived from physical materials (*e.g.*, concrete, asphalt, rooftops and grass).

10. **In terms of operational reliability, the results indicate that the per-pixel maximum likelihood classification of transformed and non-transformed Landsat TM data offers limited success for classifying land use and land cover types. Categories classified with acceptable reliability may be used as a framework for the addition of residual classes through a more conventional approach (*i.e.*, photointerpretation).**

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Mr. SHAYS. I just have one question. It's not my practice to come late to a hearing and ask a question. And if it's been asked, Mr. Chairman, I'd like to know it and not even have the panelists answer it, but I'm interested to know if the various countries dealing with the satellite programs—our Landsat and various comparable ones—really look for the same information.

If that's been asked, then my time is used up. Has it been asked?

Mr. SCHEUER. That hasn't been asked.

Mr. SHAYS. I'd just like to know if we're looking basically for the same general information because it seems inherently so logical that there should be coordination.

Mr. SHUTKO. As I said in my presentation, we feel now in the Soviet Union our newest type of optical system obtains data from this satellite and this data is similar to data which can be taken from Landsat. Our officials are ready to distribute this data for possible consumers.

Mr. SHAYS. But let me ask you this, to be a bit more precise. It strikes me that Landsat and comparable systems have a variety of uses. There's a lot to discover, a lot to learn. Is the approach of the various countries pretty much the same in terms of what they would like to learn from their systems? Is that question clear?

Mr. LASERSON. Congressman, I suspect that the answer to your question is really is a function of what the user is going to do with the raw data rather than asking what the different originators of the raw data are going to do.

We might all produce the same data in the competing systems, but depending on what the end product will be and what the user is going to do, there can be different aspects to it.

I'm a novice in this, but that's the way I suspect the question should be answered.

Mr. SHAYS. Well, if you're a novice, I'm even more of a novice.

Let me make this point. It seems to me, then, what I hear you saying is that we're going to get some of the same data but we're going to use the data differently depending on interest. So it's conceivable then to have one comprehensive system with a variety of people marketing data, correct?

Mr. LASERSON. Perhaps depending on the relative qualities of the data also, because even though we may be looking at the same part of the Earth, because of the attributes of the cameras, we may come out with different results as well.

Mr. Shays. Thank you very much. Mr. Chairman, that's really all I wanted to ask. Thank you.

Mr. SCHEUER. Thank you, Congressman Shays. You certainly asked a very perceptive question.

It seems to me that as we proceed ahead that the variety of needs of the users will power the provision of different services, a more heterogeneous an pluralistic package of services, by the suppliers. You can't consider what the suppliers are going to produce separate from what the market is going to demand and I don't think we can predict right now. I think this will all have to evolve and it's going to be very interesting to watch this scenario proceed.

Congressman Tom McMillen of Maryland.

Mr. MCMILLEN. Thank you, Mr. Chairman.

I would like to focus in with Mr. Julyan on a question that has to do with the negotiations that took place. In testimony two years ago you did not seem enthusiastic about a U.S.-SPOT joint venture. However, in recent months U.S. and French government officials have entered into discussions concerning a possible joint venture in remote sensing.

Question number one is, very briefly, what is the status of these discussions? I know you've talked about that. But more importantly, what was SPOT's role in those discussions? Maybe you can elaborate as to some of the negotiations.

Mr. JULYAN. Congressman, the discussions between NOAA and CNES were initiated in January of this year, the formal discussions. There have been meetings on alternate sites, both in the United States and in France since that time. They are still on schedule—or they still are continuing. The initial schedule called for a first report from this group out by June. Again, not speaking for the French government but just as an observer, if I were to make a prediction, it would not be June. It would be much later on in the calendar year. But the discussions are continuing.

With regard to SPOT Image's role in these discussions, we are a very active player in the SPOT program. SPOT Image, as the commercial entity, and the commercial goals of the SPOT program, would also be included and covered by any discussions that addressed merging the SPOT program with any other program. They have the highest priority and the utmost attention and concern.

Therefore, SPOT Image has been advised, consulted, informed, and is aware of the discussions that have gone on and have had the opportunity for our comments as input to CNES for those discussions.

Mr. MCMILLEN. My followup question, after reading Mr. Vesant's comments, is that you didn't have to read about these discussions in Aviation Week, did you, as the United States company, EOSAT, did? Is that an accurate depiction?

Mr. JULYAN. That's accurate, Congressman.

Mr. MCMILLEN. What was EOSAT's role in all this? Could you elaborate on that a little bit? Do you have knowledge of any of their role? Did they participate at all?

Mr. JULYAN. I'm really not in a position to comment on that because I'm not aware of what discussions, conversation, formal or informal, might have taken place on the NOAA side in terms of information. I've read in the papers the comments of EOSAT regarding their lack of knowledge about it, but I'm really not in a position to comment on it.

Mr. MCMILLEN. Well, Mr. Chairman, I always marvel at the French and their ability to mold their public and private partnerships in good faith and so forth. It seems to me that that's lacking in this case as far as the United States' public-private partnership with EOSAT. Not only was NOAA reprimanded by the State Department and the White House for exceeding its authority on this issue, but clearly it seems to me an issue of bad faith when EOSAT has to read about these things in Aviation Week and our foreign counterpart obviously is right in the middle of these negotiations. I find that quite ironic, Mr. Chairman. I hope that we will explore

this in greater detail because I believe this is really the thrust of this issue.

Basically, what you're saying, in conclusion, is that you were involved from day one intimately in these negotiations and to your knowledge EOSAT was not; is that correct?

Mr. JULYAN. The latter comment is correct, Congressman, that I don't know what EOSAT's involvement is. The former statement in terms of SPOT's involvement, awareness and being informed is correct. The specific words that you want to use might be up for debate or discussion, but to the thrust of your question the answer is yes.

Mr. MCMILLEN. I look forward to exploring this with the governmental witnesses in the next panel.

Thank you, Mr. Chairman.

Mr. SCHEUER. Congressman Lamar Smith of Texas, please take your six or seven minutes.

Mr. SMITH. Thank you, Mr. Chairman.

Mr. Julyan, we all seem to be focusing questions on you, but one question oftentimes leads to another. That's not to say that we wouldn't have questions for others on the panel as well.

In your prepared testimony you use the word "reliable" four times in the first two pages. How important is reliability in the market and, beyond that, how reliable do you consider the United States program to be?

Mr. SCHEUER. Excuse me one moment. Just to clarify that, when you say "reliability," you mean assured continuity, do you not?

Mr. SMITH. Correct.

Mr. JULYAN. Congressman, the success of commercialized remote sensing is based on the quality of the data coming down from the satellites first and foremost. Our ability to transform that data into products for the marketplace and to ensure the continuity and availability of that data on commercially reliable and dependable terms is equally critical to our success. You must have all of these components in place or you cannot have a business. You can have an interesting program. You can do some very important R&D studies. But you cannot have a viable commercial business.

Continuity of data and our customers knowing that there will be continuity of data from the SPOT program is a key element in our ability to attract commercial users. We've been able to assure our users, from the launch of SPOT 1 in February 1986, that there would be SPOT satellites in orbit through the turn of the century. And being able to make that assurance and back it up is an absolutely critical part of establishing new markets, especially in the commercial sector.

Mr. SMITH. One more question. Do you consider the Landsat systems are largely serving different kinds of users or are they competing for the same market? In other words, is there room for all of us or are we going to end up competing with each other?

Mr. JULYAN. There's a lot of room in space and there's a lot of room on Earth and there are a lot of markets. Data characteristics today from Landsat and SPOT, just to refer to the two systems that are commercialized today, are complementary in many areas and are competitive in some. SPOT has greater ground resolution and has stereo capability which is not available from Landsat and that

clearly identifies specific markets, especially cartographic markets, that are dominated by SPOT.

On the other hand, Landsat has seven spectral bands compared to SPOT's three multi-spectral bands and that means that depending on specific applications you can extract some information from those Landsat bands that is not comparable to information you can extract from SPOT.

So on the one hand, you could speak of complementary data sources. It's true, however, that I think what's most significant from a commercial perspective—and I again remind the committee that I am speaking as a crass capitalist—that what matters is the predictability and the continuity of the data that you're sending down—not just the satellite, the source, but the data itself. Stabilize the data. Stabilize the bands that are going to be available and we'll build the markets around those bands. The markets will determine in the first instance what our band selection is. That's how we are determining SPOT 4 sensor design by the way. Then we work and serve those markets.

Mr. SMITH. Let me go back to the competing market idea. Technically, how difficult would it be to merge the different competing systems into one common system?

Mr. JULYAN. Let me answer your question in two parts. If we're on the ground, the ability to co-register or merge various data sets—Landsat, MOS, Soyuzkarta, SPOT—that's doable. Technically, that's doable. It's not very difficult—well, my technical friends would argue with that, but it's a technology and a capability that's here.

To merge the space segments implies a decision of what sensors to fly in response to both the market's comments and reaction to the activities of the various companies or countries involved, and then whatever other political or technical considerations might go into it.

It's not a question of merging in the space segment. It's a question of choosing.

Mr. SMITH. I understand. Thank you.

Thank you, Mr. Chairman. No more questions.

Mr. SCHEUER. Well, this has been a fascinating hearing. I'd like to ask the whole panel a couple of questions and some of them have been adverted to before.

Will the market in the year 2000 be large enough to support three or perhaps even four international competitors? Anybody? I know the Japanese representatives would feel that the commercial market will not be able to support even the cost of distributing the information even if the development of the satellite and the launching of the satellite were contributed free.

Do any of the others of you disagree? Looking forward a decade or more, will the commercial market support a private commercial entity?

Mr. JULYAN. Mr. Chairman, my answer, speaking now as an individual who is responsible for the U.S. business developments of SPOT, is, yes, the market will support multiple platforms. How many and which ones, are variables which would have to be addressed. But would the market support multiple platforms, my answer would be yes.

Mr. SCHEUER. Anybody else?

Mr. LASERSON. Mr. Chairman, while we are very new at developing the markets and developing our place in those markets, this project, it's my judgment on what I've determined so far that the user community is so explosive and so potential we don't know how big it can be.

I think there's a lot of work that has to be done with the user community that has perhaps not been done as busily as it might have been done.

Mr. SCHEUER. All right. Then let me ask a follow-up question. With that significant potential demand in the user community out there, what do any of you feel about the viability of an international consortium for remote sensing?

Would the Japanese representative have a view, forgetting about the commercialization because you feel for the time being that there isn't a commercial support even for distributing the knowledge that we will be producing, and you may very well be right because, as Mr. Laserson said, this demand which may be very explosive is still problematical, is still very iffy, and it may materialize and it may not.

Do you see just simply from the point of view of international cooperation on the development of the satellite and the launching that there's a justification, apart from the commercialization and some of the complicated, thorny questions that commercialization raises, is there a logical justification for a joint scientific effort and joint funding for the development of the satellite and the launch, joint sharing of both scientific know-how and funding to develop a satellite and launch it?

Mr. TADAKAWA. If I may clarify your question, is it commercially run or just the government cooperative venture?

Mr. SCHEUER. I'm talking only about a cooperative venture by governments using the capability of private corporations in the development and the launching of the satellite, leaving for future further consideration the question of commercialization, how the ownership rights to the knowledge going to be factored into the equation and so forth. Now I suggest, if there a logical rationale, a reasonable justification, for sharing of science and sharing of funding to develop the satellite and to launch it by governments? Of course, the government can use their own private contractors, the corporations that they feel have very significant capability. I guess all of the governments will use private sector groups to actually do the development work.

Mr. TADAKAWA. I am not in a position to make a comment on this issue, but in the past the Japan has participated in cooperative ventures with NASA, like the international platform where we provided sensors we developed.

Mr. SCHEUER. I think that's helpful. Thank you very much.

Would any of the other three representatives of the foreign governments who have been active care to answer that? What would the Russians, what would the French, think of the possibility of a joint effort in development and launching of the satellite, leaving the question of who owns what to another forum?

Mr. LASERSON. Well, we know there have been some tentative efforts of cooperation in space between the Soviet Union and the

United States already and I think your question goes to the nature of that type of affair.

But when we start talking about this particular industry, it seems to me that as important as the question of funding is, is the question of priorities of the flight paths of the satellites. And when we get into that kind of question to talk about cooperation between the United States and the Soviet Union requires a desire to be cooperative on a lot of other issues as well.

I think my answer to your question is, it is potential, but it is also difficult.

Mr. SCHEUER. Yes. Do you think that a bilateral or even a multilateral remote sensing program is incompatible with commercial private industry participation? Any of you?

Mr. JULYAN. Mr. Chairman, if I might, it's not incompatible. As is evident by the discussions that have been initiated between CNES and NOAA, we at SPOT believe that international cooperation is a viable alternative to explore, but it's not the only alternative to explore.

And in answer to your second question, one of the major issues that will have to be resolved is whether or not in a bilateral or multilateral consortium we can still maintain a single commercial drive and perspective for the organization, for the consortium. I'm not a politician. I'm just a businessman. So I don't know how easy it would be to handle one government. I deal with that. Two governments, yes, maybe. But after a while, I think about that and think I'm not sure that's the way to run a railroad.

Mr. SCHEUER. Well, I've only had the experience of dealing with one government and I can tell you that I don't think what we're doing in this country is any way to run a railroad. So maybe it's not just a question of multiplicity. Maybe it's a question of the character and determination and the will of the individual components that you try to meld together into a consortium.

Mr. JULYAN. My feeling is that you must have an unequivocal and clear dominance in your decision making process that will favor the commercial considerations that have to be made and that is hard to do at the same time that you balance political, technical and other concerns. You can do it. We have done it with SPOT, but that's the tricky part of it.

Mr. SCHEUER. Well, I think you're just emphasizing that this whole matter demands top level consideration in each of the governments involved and long-term priorities, a priority to fund it, develop it, and sustain it. And if we can't do that, there's no point in getting into any further discussions on sharing.

Let me ask Mr. Yamagami and Mr. Tadakawa, is it Japanese policy to make all data from all future remote sensing missions available to all users and, if so, under what conditions?

Mr. TADAKAWA. I mentioned in my statement that we are subject to two policies—Open Sky policy and Non- discriminatory data policy. That is our distribution policy. So, yes, everyone can buy Japanese remote sensing data.

Mr. SCHEUER. And it will be available to all users?

Mr. TADAKAWA. Yes.

Mr. SCHEUER. Do you plan to market your MOS and your JERS data to U.S. customers? If you do, how do you plan to approach the marketing methods by which you will do this?

Mr. TADAKAWA. We do not develop to sell the MOS-1 data and the ERS-1 data. Our agency is not a commercial company. So we do not endeavor to sell this data.

Mr. SCHEUER. Thank you.

Mr. Tadakawa, I'm a little confused. If you're making it available to all comers, including customers in the United States, but you're not selling it—

Mr. TADAKAWA. No, no, no. We receive the data from the satellites and then another agency is to sell the data.

Mr. SCHEUER. I see. They will sell the data. You have another marketing agency.

Mr. TADAKAWA. Yes.

Mr. SCHEUER. In other words, you're not marketing it yourself in your agency?

Mr. TADAKAWA. We will not sell the data.

Mr. SCHEUER. You will not sell the data, but another marketing agency of your government will sell the data?

Mr. TADAKAWA. Yes.

Mr. SCHEUER. Can you tell us, will the data be sold by them to all comers, including American customers?

Mr. TADAKAWA. Yes.

Mr. SCHEUER. And do you have any idea of how they will plan the marketing program to sell this data to American customers as well as customers around the world?

Mr. TADAKAWA. My understanding is that NASDA doesn't sell the data unless it is done by a non-profit organization which is like U.S. government agencies like NTIS or other federal agencies.

Mr. SCHEUER. So you wouldn't market it from the point of view of making a profit. You would market it as a non- profit activity?

Mr. TADAKAWA. Yes. Our distribution fees are based on operational fees but are subject to international practice. So even if the operational fees are higher than the money gained by selling the data we will decrease the prices.

Mr. SCHEUER. Well, you may decide when it comes to distributing it to commercial customers like commercial development groups, mining and oil exploration and the like, you might decide to distribute it on a commercial basis, but I think the fact that you're thinking about distributing it on a non-profit basis augers very well from the point of view of the developing world.

They have an enormous need for data on how to manage all of their resources, on the development of their mineral resources, on the development of their agricultural resources. As I said before, knowledge about when to plant, when to fertilize, when to irrigate, when to sow, when to reap. The management of pests that afflict their agriculture, the management of blight that afflicts forests, their forest management, their husbandry of all of their natural resources and mineral resources. This will be a marvelous service if you could contemplate giving that at little or not cost to the developing world.

This would be a whole new role for Japan as an aid donor, as a leading aid donor. You now are the number one aid donor around

the world and you should be very proud of that role that you're filling, and this would be making that role of yours even more significant because you would be the number one nation not only in funding aid to the developing world, but here you would be contributing a vital and priceless service, facility, wisdom, knowledge to developing countries. And I think it would enormously enhance the deserved reputation that Japan is accruing for being the number one aid donor in all the world. That holds out enormous hope for the developing world.

Mr. TADAKAWA. Can I make a comment?

Mr. SCHEUER. By all means.

Mr. TADAKAWA. We'd sold the data for only $1 million and we spent ten million dollars for the operation, so how can I operate commercially?

Mr. SCHEUER. Well, we don't have time enough to get into that today, but hopefully when the Science Committee comes to Japan we can get into that. But I just want to check that I'm correct in your saying that you will offer a great deal of data on a non-profit basis, at little or no cost, especially to the developing countries. Am I correct in that understanding?

Mr. TADAKAWA. I'm not sure who will buy the data but the Republic of China buys the SPOT data and the Landsat data and also the Japanese National Institute is a government institute that buys data.

Mr. SCHEUER. Well, I'm not sure we have reached a complete understanding and there is a language problem here which I regret, but I am enormously encouraged by what I think your answers are and I just repeat that Japan has already passed the United States and is the number one financial aid donor. But there have been comments around the world that Japan, while being number one in financing aid, has not yet developed as much capability as it could in designing creative programs.

You have a very small professional establishment for aid, very much smaller than many other donor countries, and you tend to respond to requests for aid rather than initiate programs that are designed to help the developing world. This is one area in which you are capable of achieving enormous creative input by designing these satellite data programs to fit all of the multiple needs of Third World countries, and this I think would give you an enormously enhanced capability, a very creative capability of helping Third World countries. And I congratulate you on that.

Mr. TADAKAWA. Thank you very much.

Mr. SCHEUER. This has been a very productive panel for us. We have enjoyed it very much.

We may have some further questions for you by mail and I would ask unanimous consent to keep the record open for ten days or two weeks at the most in the event that members do have questions to submit by mail. We thank you very much for a very stimulating and very creative panel. Thank you so much.

We now proceed to panel two, international satellite consortia: the pros and cons, more or less an elaboration of the questions that many of us have been asking.

We will hear from Dr. John McElroy, Dean of the School of Engineering at the University of Texas; and Mr. Jerry B. Caseman of the Harris Corporation.

Dr. McElroy, why don't we ask you to start off. Why don't you take, since this is a smaller panel, take six or seven minutes and just chat with us informally and don't hesitate to advert to anything that you've heard this morning either from the witness or the questions from up here and, of course, for both of you, your full prepared statements will be printed at this point in the record, the point at which you testify. So take your six or seven minutes, Dr. McElroy, and when we've heard from Mr. Caseman I'm sure we will have some questions for you.

STATEMENT OF JOHN MC ELROY, DEAN, SCHOOL OF ENGINEERING, UNIVERSITY OF TEXAS AT ARLINGTON, ARLINGTON, TEXAS.

Dr. MCELROY. Thank you, Mr. Chairman. I'm very glad to again be before the panel. Certainly the record of the hearings of this panel and this committee are probably the most complete record of the history of remote sensing that exists anyplace.

Let me take you through not my prepared statement but just a few observations about the events surrounding remote sensing in the United States and let them sort of speak for themselves as to what conclusion one can draw.

The first step that we should do—and I hate to take anyone back to the Carter Administration, but the Carter Administration had developed in 1978-79 a sound plan for the commercialization of remote sensing which involved, interestingly enough, four spacecraft—Landsats 4, 5, 6 and 7.

The assessment of the market was that it was going to require four spacecraft to develop a commercially viable market and that in parallel with that we should, in addition, have seed activities conducted by the National Aeronautics and Space Administration to sponsor test projects of the agristars sort and various others.

In 1981, the plan was junked. We then went to a two spacecraft system, not on the basis that there was any rationale within the commercial sector that a two spacecraft system was sufficient, but simply because that was a convenient target which could be eliminated.

I might observe that when we are spending some $20 to $25 billion a year on our total space program, the savings on a percentage basis by attacking one of our few commercial attempts is relatively modest at best.

Now following up on that, of course, the next events that took place were we cancelled all of the seed activities within NASA and then we added to that a cancellation of all future satellite R&D on new remote sensing instruments for meteorology. So we got out of that business as well.

We then went into a series of lengthy discussion about commercialization of the land and weather satellites. This panel was actively involved in that process. We finally ended up with the resignation of a deputy secretary of Commerce on some allegations

which were never brought to trial but which were quite serious and which are well documented in the record of this committee.

Now going back to this four spacecraft plan that the Carter Administration had put forward, there was another small ingredient which was implicit in that plan; namely, that we would go through that without extraordinary disruption. And, of course, the commercial sector in looking at all these events even from '78-79 up through the Landsat Commercialization Act of 1984 saw anything but clear direction from our government.

Then we started into the Landsat Commercialization Act itself and the disruption continues. The simple truth of the matter is that in the absence of a firm government commitment there is probably no real solution to land remote sensing in the United States. We might as well go ahead and let the French do it.

My own case, what I've been trying to do is try to keep the United States in the ballgame. I have tried every scheme that I can think of to come up with a strategy which would allow the U.S. to participate and participate vigorously in a market which will inevitably develop.

The facts, though, are quite simple. The facts are that, by all estimates, we are going to have revenues of the order of $50 to $100 million a year from our data sales, from the data sales that are accessible to the actual developer of a spacecraft system. In other words, I'm neglecting the second and third order sales that go out well beyond that entity's reach.

Therefore, I've looked to see, first of all, is an international consortium reasonable? I believe that it is. We have traveled that path before. We have done it on a private basis with INTELSAT and INMARSAT. Other countries have done it in the case of EUROSAT in Europe. We've done it on a government-to-government basis in the case of the search and rescue program. So international consortia are indeed feasible on whatever basis one chooses to go.

Finally then, the thing that I've looked at has been to say, well, how do we at least secure the future of an American involvement in this? One way to do that would be to revisit the question of commercialization of the weather satellites. Since we are doing no advance development work in any event on the weather satellites, we are now at a fixed complement of instruments for the foreseeable future. They are operational instruments in every respect.

The procurement of data from those satellites is the procurement of data, underline data. It is not the development of new advanced R&D. Therefore, it seems reasonable that now that we're past the turmoil and controversy of the early '80s surrounding that decision that perhaps we might revisit it in light of the fact that they are operational and could be the data that underwrite the data sales I should say that underwrite a U.S. commercial venture.

I have therefore proposed that one of the first things that we might do would be to revisit that question, consider having a U.S. entity. We have one now EOSAT. That would be a reasonable choice from my perspective. Take over that total operational job, recognize that the satellite budget within NOAA is a data purchase budget. That's all it is. And go ahead and proceed.

Once you have the U.S. house in order, then it would certainly seem reasonable to consider international cooperation or collabora-

tion or consortium or what have you. I am very much an internationalist in this business. I believe that is a viable way to proceed. I am very reluctant, however, to shoot our own entity, INTERSAT, or another designee if that happens to be the case, in the leg before they go into international negotiations, but send them forth with a strong, positive position, stated clearly and forcefully by our government, and then they can negotiate effectively.

I believe under the current circumstances they do not have such power because they are undoubtedly a lame duck and I believe that the NOAA negotiations with CNES are inevitably going to be perceived the same way. NOAA will be in a disadvantaged position in negotiating with CNES.

I'll stop there, Mr. Chairman.

[The prepared statement of Dr. McElroy follows.]

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PRESENTED BY WITNESS

May 9, 1989

Statement of

Dr. John H. McElroy
Dean of Engineering
The University of Texas at Arlington

Hearings on

The Future of the Landsat System

Before the

Subcommittee on Natural Resources, Agriculture Research, and Environment and
the
Subcommittee on International Scientific Cooperation
Committee on Science and Technology
House of Representatives

Mr. Chairman and Distinguished Members of the Subcommittee:

I am pleased to again have the privilege to speak to the subcommittees on the important topics of international cooperation and commercial opportunities in earth observations from space. My remarks are from the perspective of a person concerned about space applications and one who believes that we should be extracting the maximum national economic benefit from our activities in space. They are based on my personal experience as an executive in the National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and Hughes Aircraft Company. I have no personal role in earth observations, or in any of these organizations, aside from serving in an advisory capacity from time-to-time.

Introduction

Earth observations is one of the great success stories of the space age. Since the advent of the weather satellite, no hurricane has approached the coast of the United States unannounced. Countless lives have been saved and incalculable

property damage avoided. The land-observing satellites have provided new insights into geology and land use, and opened new paths in exploration for resources. The ocean-observing satellites have revealed new information about sea circulation, waves and height, temperature variations, and phytoplankton distributions.

In sum, man's understanding of the planet has been advanced remarkably by space observations of the radiation fields around the earth, the atmosphere, oceans, land, and biosphere.[1] The continued development of that understanding is a major international research program of the 1990's.[2]

The advance of earth observations from space has not been confined to the United States. Brazil, Canada, China, the European Space Agency, Federal Republic of Germany, France, India, Italy, Japan, the United Kingdom, and U.S.S.R. all have space programs, and many more nations have research and operational programs based on the use of data from other countries' satellites.

Advances will continue in research, operational, and commercial programs. With success, however, come questions and opportunities. The development, launch, and operation of earth observations satellites, and many aspects of extracting information from their data streams, have been reduced to well-understood engineering practice in the United States and abroad. A reasonable question is whether it is now timely to give private industry a greater role in what has been largely a government activity, and whether to do so in an international context.

Commercial Space Activities

The possible commercial activities in space range from proven successes, as in space communications, to speculative new opportunities offering future rewards, e.g., materials processing. In the former, only a limited further government role is required--namely, securing international frequency allocations, protecting U.S. commercial interests, and providing seed technology for future spacecraft. In the latter, the government role lies in providing experimental flight opportunities that allow the commercial sector to seek information for future investment decisions.

In both instances, the government's objective is to stimulate the creation of largely self-sufficient, commercially successful, private ventures with a minimum of participation by the government. However, longstanding government policies, in both Republican and Democratic administrations allow another commercial activity as well. It is a venture based upon the policy mandating that the government obtain from the private sector--where cost effective--the goods and services it requires, rather than producing them itself.

In complying with this policy, the government cannot, therefore, simply encourage the commercial exploitation of private markets; the government must also provide, where feasible and efficient, a market based on its own needs for goods and services. Remote sensing is an opportunity for the private sector that fits this description.

A Policy Framework and Action Plan for Remote Sensing

The principle of the government relying upon the private sector for goods and services was most recently articulated in President Reagan's space policy, and similar statements were released by past administrations, notably in President Carter's. The statements in the space policy provide not only a framework for remote sensing, but a plan of action for a successful commercial venture. President Reagan's space policy says (as described in the unclassified press statement released by the White House[3]):

> *The United States government shall not preclude or deter the continuing development of a separate, non-governmental Commercial Space Sector. Expanding private investment in space by the market-driven Commercial Sector generates economic benefits for the Nation and supports governmental Space Sectors with an increasing range of space goods and services.*

The policy also says:

> *Governmental Space Sectors shall purchase commercially available space goods and services to the fullest extent feasible and shall not conduct activities with potential commercial applications that preclude or deter Commercial Sector space activities except for national security or public safety reasons. Commercial Sector space activities shall be supervised or regulated only to the extent required by law, national security, international obligations, and public safety.*

and:

> *Agencies will seek to promote private sector development and implementation of applications. The policy also states that: Such applications will create new capabilities, or improve the quality and efficiency of continuing activities, including long-term scientific observations.*

Further:

> *To stimulate private sector investment, ownership and operation of space assets, the directive provides that the United States Government will facilitate private sector access to appropriate U.S. space-related hardware and facilities, and encourage the private sector to undertake commercial space ventures.*

Finally:

> *The directive states that the governmental Space Sectors shall, without providing direct Federal subsidies: Utilize commercially available goods and services to the fullest extent feasible, and avoid actions that may preclude or deter commercial space sector activities except as required by national security or public safety. A space good or service is*

"commercially available" if it is currently offered commercially, or if it could be supplied commercially in response to a government service procurement request.

In the following paragraphs, these policy statements will provide a guiding overlay on the nation's current activities in remote sensing. The discussion will begin with a brief examination of the duplicative activities now supported.

Duplicative Federal Support to Civil Remote Sensing

The federal government supports three civil remote sensing systems. The first is that of the National Aeronautics and Space Administration (NASA). The second is that of the National Oceanic and Atmospheric Administration (NOAA). The third is the commercial venture called the Earth Observation Satellite Company or EOSAT.[4]

NASA conducts advanced research in remote sensing. It operates or plans to operate satellites in polar, inclined, and geostationary orbit.[5] The satellites are built and operated by the private sector, and sometimes involve international joint ventures.

NOAA is responsible for operational remote sensing satellites to collect atmospheric, oceanic, space environment, and land data to meet governmental needs. The satellites also provide data collection and search & rescue services. NOAA operates two operational satellite systems, each made up of two satellites, one system in polar and a second in geostationary orbit. The systems are built and largely operated by the private sector. The polar-orbiting spacecraft contain hardware provided by Canada, France, and the United Kingdom.

EOSAT has been awarded through a competitive process a government contract to operate the Landsat system, develop the next satellite in the series, and market the data products. An eventually self-sustaining commercial venture is sought. The Landsats are polar-orbiting spacecraft. These spacecraft are also built and operated by the private sector.

Thus, the U.S. government funds three systems that are built and operated by the private sector, although to government specifications and with government participation in operations in some cases. All three systems require federal funding for their continued existence, because even the private EOSAT system does not receive enough revenues from data sales to sustain itself fully.

Even though the government funds all three, the government currently in essence forbids itself from benefitting from economies of scale. For example, NOAA is currently barred from providing space on its morning polar-orbiting satellite for the EOSAT sensors. Similarly, EOSAT is barred from flying the NOAA sensors or providing the government-required data from its spacecraft. Finally, NASA has no plans to use the EOSAT spacecraft on a long-term basis to carry some of its research sensors, although it is an agreement has been prepared on a joint venture with EOSAT on an ocean color instrument.

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Thus, in the absence of any modifications to existing practice, as opposed to policy, the government can either continue to fund three systems or dispense with one or more and deny itself the data and/or commercial opportunity. In any event, the current net cost is greater than it need be and the practice is inconsistent with the above space policy, in that a government system is supported rather than relying upon a commercial one for required data and because the government system in some respects competes against the commercial system.

The Market for Remote Sensing Data

The present market accessible to EOSAT is small ($20 to $40 million per year) under current practice, although it is expected to grow over the long term. This level is sufficient for the capitalization and operation of a sensor, but not for the development, launch, and operation of an entire space system. The government's options are: (1) to continue to fund EOSAT at nominally $50 million or more per year for the development and operation of each successive Landsat until the market becomes large enough to realize revenues that make EOSAT self-supporting, (2) terminate funding for EOSAT at some point and rely upon experimental or foreign data, or (3) seek a more efficient system approach.

NOAA's satellite activities, on the other hand, are projected, when last I looked, to require nominally $350 to $400 million per year for the foreseeable future. As noted above, the motive for this funding is data, not the development or manufacture of spacecraft and associated systems and their operation. Thus, the significance of this budgetary figure is that it measures the value that the government places on these data, i.e., it is the size of the federal market for these data. The government's options are: (1) to continue to fund NOAA at either present or reduced levels (with reduced services in the latter instance) or (2) seek partnerships with EOSAT or another entity to reduce the combined EOSAT and NOAA funding.

Opportunities for Partnerships

There are many possible partnerships between private entities and NOAA that might be considered. Two are: (1) Allowing EOSAT to place its sensors on the NOAA polar orbiters, while maintaining a separate identity for the commercial data stream flowing from the spacecraft and continuing separate data processing facilities, or (2) Tasking EOSAT or another entity to assume the responsibility for the overall operation of the NOAA satellites and the provision of specified data to the government under government-determined conditions. The latter would offer the greatest opportunities for economies of scale and scope, but would also vest the greatest responsibility for required government services with the private sector. The latter being a positive feature for some and a negative one for others, depending upon political philosophy.

In the first example, the government would fund one fewer launches and one fewer spacecraft per polar constellation, by maintaining two polar-orbiting satellites in operation rather than three and assuming that the lifetime of the combined spacecraft is equal to that of the current NOAA satellites. In the second example, those benefits would be realized and augmented by economies of scale in tracking

and data systems. In either case, the net cost to the government would be less after the initial transition period is completed.

With respect to NASA-EOSAT partnerships, the current joint-venture with EOSAT can be encouraged and expanded upon as feasible. The principal requirement is to lower any barriers to NASA relying upon the private sector, whether EOSAT or another entity, to carry and operate its research sensors.

A National Role for the Private Sector

Rather than considering generalities, one possible scenario will be discussed, the transfer of the entire satellite arm of NOAA to the private sector. As noted above, the objective is to fly two polar-orbiting satellites instead of three. One would cross the Equator in the early afternoon at the time of the present NOAA afternoon polar orbiter. The second would cross in the early morning at a time selected as a compromise between the current Landsat and NOAA morning polar orbiter times. In addition, two geostationary satellites would remain the normal configuration, one directing its attention from the central United States out into the Atlantic Ocean and the second overlapping the mid-continent coverage of the first and extending coverage out into the Pacific Ocean.

The early afternoon polar-orbiting satellite would carry a complement of NOAA operational instruments and retain its position as the prime satellite for weather forecasting. Added to the satellite would be instruments requiring a high sun angle.[6] The early morning polar-orbiting satellite would carry the NOAA instruments and continue its role as a backup to the afternoon satellite, and a means to increase the frequency of sampling various phenomena. Added to the satellite would be the Landsat-like instruments that have traditionally used that orbit.

A merged data processing system would encompass both the commercial and government data streams, with different paths taken after initial processing. The government data would be provided to NOAA and other government agencies under the same terms and conditions as at present. Those agencies would distribute the data as they see fit under terms they would stipulate in the contract with EOSAT or another entity. The direct broadcast environmental data would continue to flow to domestic and foreign entities under the same conditions as at present. The private entity would simply replace the satellite arm of NOAA as the source of government data.

The private entity would also replace NOAA as the recipient of the foreign instruments provided by Canada, France, and the United Kingdom. The government would necessarily establish a process for negotiating future agreements, and may simply retain its current role, so that EOSAT or another entity would serve as the government's carrier for the foreign instruments.

In the case of France, the ARGOS data collection system is now operated by a private entity formed exclusively for that purpose, so there should be no inhibition to dealing with a private American entity. For search and rescue, the Canadian and French hardware are carried on the NOAA satellites as a "piggyback" payload that is a part of an international system. Whether the satellite carrying the system is a

7

governmental one or a private one operating under government contract is irrelevant.

The remaining sensor supplied by the United Kingdom should similarly present no problems. The United Kingdom would reach agreement with NOAA to develop and fly an advanced sensor; NOAA would then choose to fly the sensor on a commercial satellite under government contract, but return data to the United Kingdom as it has done in the past.

Thus, there would be no substantive change to current data practices, and certainly no commercialization of the National Weather Service, its functions, or any data related to the protection of the life and property of the citizens of any nation. The international community would still receive the data it currently receives, so no adverse foreign reaction would be forthcoming and no damage done to the extensive programs by which nations exchange data from terrestrial and space sources. The following benefits would be realized:

- o Economies of scale in space systems;
- o Economies of scale in ground tracking & data systems;
- o An assured market for the private sector to build upon
- o An expanded private sector role in space
- o A reduction in direct government activities and long-term further reductions in government outlays as the private market develops and reduces the cost of government-purchased data
- o A continuing commercial program could also carry research payloads on a space-available basis, and provide a cost-effective alternative for NASA.

The current difficulties in Congress and the Administration over the funding of EOSAT would be dramatically lessened, because sufficient funds are realized from Landsat data sales to fund the marginal cost of adding Landsat-like sensors to a core mission that is supported to serve governmental needs.

As the market for Landsat-like data products expands, as it inevitably will, the commercial business can become the principal activity of the private entity and the governmental customer can benefit from a reversal of the situation in which it becomes the funder of marginal instead of core costs.

Thus, as an early NASA contract underwrote the beginnings of the International Telecommunications Satellite organization (INTELSAT),[7] a government contract for needed services can underwrite a new commercial venture. Today, both the government and private sectors benefit from the availability of low-cost, efficient international telecommunications that have evolved from that initial contract. The same can happen in remote sensing.

It is vital to note that no element of this scenario involves a subsidy by the government. The government contracts only for those data and services that it requires under terms and conditions that it specifies. Thus, the government spends no funds that it would not otherwise spend and loses no control that it does not wish to give up.

The above scenario would require a modification of the Landsat commercialization legislation, but it seems likely to me that a properly formulated proposal to the Congress would be looked upon favorably that carefully addresses all public safety and international issues, that offers legitimate cost savings, and serves the bipartisan objective of increasing private activities in space. Of course only you can make that judgment.

An International Evolution

The discussion to this point addresses principally the domestic scene, but remote sensing is an inherently international subject and even greater economies are available by acknowledging and exploiting its international nature. The domestic systems of nations can merge into a common international system. For the United States, however, the step toward an international system must be preceded by the establishment of a secure domestic entity, otherwise the United States would be in a position of weakness in any negotiations. Thus, the use of the term "evolution" in the title of this section is deliberate and not at all casual.

Mention was made above of INTELSAT; the International Maritime Satellite organization (INMARSAT) could have been mentioned as well. In both instances, an inherently international need (nation-to-nation and ship-to-shore communications) led to countries joining together to create unified, collectively-funded systems. The bulk of international communications can be easily handled by no more than a few systems; modern technology has produced systems having a high capacity in comparison to total world needs for communications. There are, therefore, compelling reasons for seeking economies of scale and scope in communications.

The same is true in remote sensing. A relatively few number of satellites--particularly in comparison to the numerous experimental satellites that will be flown over the next decade--can meet the core, continuing needs of all nations. After nations have demonstrated their technical capability with experimental or first-generation commercial systems, and after they are convinced that their industries can compete effectively for business from an international consortium (which may be as much a function of the bylaws of the consortium as inherent technological capability), the economies of scale and scope previously found in communications will be sought in remote sensing as well. It should be noted that in both INTELSAT and INMARSAT the United States has chosen to be represented by a private firm, COMSAT.

The space engineering situation is unlike that which existed during the formation of INTELSAT, in that many nations now possess the scientific and technical skills to participate in the development of the space hardware, while only the United States had such skills in the 1960's and early 1970's. The United States cannot dominate a new international space organization, nor behave in a manner

that could be perceived as domineering or authoritarian. Other nations have capabilities, resources, and interests that deserve their being treated as full, equal partners. At the same time, the United States must not enter any negotiations for a new international cooperative venture in a weak bargaining position.

Following the above scenario, a private entity, perhaps EOSAT, could be an analog to COMSAT and an international entity that might be called ENVIROSAT could be the INTELSAT analog. Elsewhere I have named the U.S. representative ENVIROSAT-USA and the international body ENVIROSAT-International.[8] Of special pertinence, both INTELSAT and INMARSAT began with negotiations and agreement among only a few nations, and ENVIROSAT could as well. It is not necessary to begin in plenary session with all of the possible eventual partners.

A crucial hurdle would be the negotiations between France and the United States to seek a merger of the commercial remote sensing interests of SPOT[9] and EOSAT that I believe to be underway, at least by press reports. However, I am very much concerned that we are not bargaining from a position of strength. Our Landsat program has been effectively crippled by indecision and lack of support. We cannot off-load our problems by entering into negotiations in which we are asking another nation to solve our problems for us. The only outcome possible from such negotiations is that the U.S. will become the weak partner dependent upon the stronger one.

In a merged land-weather system, the U.S. would have much to offer to the French through its support of a core environmental data and services purchase and its technologies, and the French would likewise have much to offer the United States in satellite and launch vehicle capabilities and international marketing relationships. The bargaining positions would then tip in favor of the United States.

Other nations that could be involved at an early point would be Japan (because of its major present and planned program), Canada, and the United Kingdom (the two other participants in the current NOAA satellites). The incorporation of the U.S.S.R. has been deliberately avoided in this scenario, because I assume that will be a political issue outside my expertise.

The desired initial outcome would be a unified international polar-orbiting remote sensing system. Other nations could be added as agreed to by the founding nations.

Still other international economies are available as well. In geostationary orbit, the world is encircled by environmental satellites of Europe, India, Japan, and the United States, with other planned by the U.S.S.R. and possibly China. A total of five satellites offers comprehensive coverage of the earth from the high latitudes (both North and South of the Equator) through the tropics.

Rather than each nation or region designing, developing, launching, and operating its own geostationary environmental satellite, it would be more efficient to procure jointly a standard satellite and operating system. Again using the INTELSAT and INMARSAT examples, the procurement of a large number of identical communications satellites has been found to be cost-effective, and the same would be true of the geostationary weather satellites. This could also be a

function of ENVIROSAT-International, and still further efficiencies and economies achieved in the global dissemination of satellite data products.

ENVIROSAT and Research

The designation of a private entity or the establishment of an ENVIROSAT is compatible with continued national research programs in earth observations. The United States and other countries have found it desirable to maintain research programs in communications satellites, even though such systems are a long-standing commercial success. It will similarly remain in nations' best interests to continue to develop advanced sensor systems and to conduct programs of advanced research based on data from those sensors and from ENVIROSAT as well.

The role of a private entity domestically or ENVIROSAT on an international basis would be to produce efficiently the standard data products upon which nations have come to rely, and to offer non-standard products when it can do so cost-effectively and without interfering with its core work. Such operational entities cannot replace all future research satellites. Specialized short and long-term research missions will continue to be flown, but with the distraction of sustaining operational sensor systems largely removed from the government.

In addition, ENVIROSAT would be well suited to conduct the very long-term (twenty or more years) measurements associated with the Global Change program.[9] Taking carefully controlled measurements of a consistent type over a twenty-year period is more characteristic of an operational activity, even though the resulting data is for research.

New Market Opportunities for ENVIROSAT

The merger of the government and private operational systems offers still other opportunities as well. While there is no intent to change the manner in which the public obtains satellite-sensed data from the government, this does not mean that the data provided to the government are without market value.

The government data could become marketable by combining it with the data from a commercial sensor or other sources to create new data and information products. The sensors from which the government data are derived can also evolve to produce new refinements in addition to the core data. Further, the earth observations entity could provide unique distribution channels to transmit the government data to segments of the public who currently have no effective access to it. Each of these offers new commercial opportunities that can ultimately reduce the cost of data to the government and increase the profitability of an ENVIROSAT.

The operators of the French SPOT system have already recognized this opportunity. They intend to add to a future SPOT satellite an imaging sensor that is comparable to that used by the U.S. polar-orbiting weather satellites, the Advanced Very High Resolution Radiometer (AVHRR). The French believe that its wider swathwidth and coarser spatial resolution will be a valuable complement to their commercial high-resolution sensor.[10]

ENVIROSAT and the Space Station Program

During the early phases of the international space station program, considerable thought was given to the deployment of large, astronaut-tended earth observation platforms in polar orbit. These were to be provided by the European Space Agency (ESA) and the United States, with a possible Japanese platform coming later. While polar platforms remain a part of the international partners' plans, the aftermath of the Challenger accident has eliminated the possibility of astronaut operations from the Shuttle in polar orbit.

NASA is now investigating robotic servicers deployed from expendable launch vehicles for such orbits. My personal opinion is that, while such a technological development is highly desirable and should be pursued as a continuing research objective, its realization will be costly and too distant to affect our planning for this century.

Therefore, the planning for either a national operational system under private management or an international system under ENVIROSAT must rely upon the use of proven expendable satellite technology. At some future time, as astronaut or robotic servicing of polar-orbiting satellites becomes feasible, a transition to serviceable spacecraft could be made.

ENVIROSAT and National Security

There are two immediate issues related to national security that affect the creation of an earth observations entity. First, the sensor complement and capability are of potential concern to national security agencies. Second, the NOAA polar-orbiting satellites serve as a backup to the U.S. Air Force's Defense Meteorological Satellite Program (DMSP).

When weather satellites were first launched, there were mild protests about what they might "see," even though their spatial resolution was exceedingly coarse. As nations became accustomed to weather observations, and more importantly began to benefit from them, the protests vanished. In a similar manner, the appearance of the first Landsat with an 80-meter spatial resolution produced some short-lived concern, but later the Landsat Thematic Mapper's 30-meter resolution and the SPOT sensor's 10-meter resolution were accepted with equanimity.

More recently, the Soviet Union has released selected panchromatic data with resolution much better than 10 meters, and a gradual movement of civil capability toward 1 meter is inevitable. What is not inevitable, however, is the speedy development of a market for multispectral digital data at that resolution. Processing capabilities and the existence of numerous markets that are well-served by coarser resolution data will delay the market growth at very high spatial resolution. Panchromatic data, which has less demanding processing, serves a substantial fraction of the high spatial resolution market and complements well the more versatile multispectral data.

In any event, the United States cannot prevent the continued growth of other nations' capabilities, and recognizing that inability the recent space policy has another important section[3]:

The directive states that the United States Government will: (1) encourage the development of commercial systems which image the Earth from space competitive with or superior to foreign-operated civil or commercial systems; . . .

Therefore, the issue of imaging capability becomes one of commercial competitiveness, and there is no *a priori* reason to assume that any restriction will be imposed that would make ENVIROSAT fail commercially.

With regard to the backup role the NOAA satellites play to the DMSP, there appear to be no plausible reason for legitimate defense needs not being met in a commercial environment, whether domestic or international. Consider first assigning to the private sector the role of U.S. civil operator. As in other areas, it becomes simply a matter of assuring that the terms of the contractual arrangement satisfy defense needs.

In the establishment of an international ENVIROSAT entity, the defense community would still have full access to civil meteorological satellite data through the same channels they use today. NOAA serves as the interface with the international community and as the source of the civil weather satellite data; it would continue to do so in the future. The only change would be the loss of unilateral control over the spacecraft and their data stream. That is a small price to pay to obtain the other national benefits. Further, in nearly thirty years of U.S. civil weather satellite operations, there has never been a defense requirement that could not have been satisfied by an entity of the form proposed for ENVIROSAT.

This discussion has avoided intentionally the issue of international peace-keeping satellite systems or United Nations satellite monitoring agencies oriented toward security issues.[11] I am not prepared to provide answers to all of the questions that such proposals raise. What is proposed here could be a start toward such a system, but only unintentionally. The purpose is simply to propose a long-term solution to meeting global needs for earth observations data in the most cost-effective manner.

Conclusions

There is a path to continued development and commercial success in remote sensing. It has administrative and legislative hurdles that must be leaped domestically and careful negotiations to be conducted internationally. But the steps that must be taken are straightforward to define and the presidential policy framework needed is already in place. It is a matter of recognizing that it is not sufficient simply to direct EOSAT to go and make remote sensing a commercial success; it is necessary to examine the total spectrum of remote sensing activities and to accept the primary role of the private sector as the preferred supplier of needed government goods and services.

Finally, it is necessary to recognize that earth observations from space is an international matter supported by a capable global industry. The United States can take a leadership role in advancing new cooperative agreements that can expand

capabilities and reduce costs or it can allow others to lead. The path is inevitable, only the players and the leaders are not.

Notes

1. J. H. McElroy, "Earthview--Remote Sensing of the Earth From Space," in A. Schnapf, ed., *Monitoring Earth's Oceans, Land, and Atmosphere from Space--Sensors, Systems, and Applications, Progress in Astronautics and Aeronautics*, 97:3-47, (New York: American Institute of Aeronautics and Astronautics, 1985)

2. R. E. Arvidson, D. M. Butler, and R. E. Hartle, "Eos: the Earth observing system of the 1990's," *Proc. IEEE*, 73:1025-1030 (June 1985); F. P. Bretherton, "Earth system science and remote sensing," *Proc. IEEE*, 73:1118-1127 (June 1985); Earth System Sciences Committee, NASA Advisory Council, *Earth System Science Overview, A Program for Global Change* (Washington: National Aeronautics and Space Administration, 1986); and Science Steering Committee for the Earth Observing System, *From Pattern to Process: The Strategy of the Earth Observing System, Volume II* (Washington: National Aeronautics and Space Administration, 1987)

3. The White House, Fact Sheet, "Presidential Directive on National Space Policy," February 11, 1988

4. EOSAT is a company formed as a joint venture by Hughes Aircraft Co. and RCA Corporation (now General Electric Co.) that was competitively selected to become the U.S. operator for the land remote sensing system, Landsat, and developer of future Landsat satellites and ground stations. The Land Remote Sensing Act of 1984 provided for the transfer of Landsat from the government to the private sector and prohibited the commercialization of the U.S. weather satellites.

5. In this testimony, the term "polar orbit" refers to a near-polar, sun-synchronous orbit whose orbit plane is nearly aligned with the Earth's polar axis, and whose altitude is chosen to cause the satellite to fly over the Equator always at the same time of day. For a typical weather or land satellite, the orbital altitude will be nominally 800 km and the time for one orbit about 100 minutes. The morning weather satellites typically cross the Equator southbound between 0600 and 1000 local solar time, while the afternoon satellites cross the Equator northbound between 1300 and 1500 local solar time. The land satellites typically cross the Equator southbound between 0800 and 1100 local solar time. Polar orbit is used for precision measurements from a vantage point relatively close to the Earth. The inputs to the National Weather Service's numerical weather forecast models come from the NOAA polar orbiters, for example. With two satellites in orbit, each point on the Earth is sampled four times a day. Inclined orbits are those that are neither polar nor in the Equatorial plane. Because they do not cross the Equator at a constant time, they are used to remove diurnal effects in measurements, e.g., tidal effects. Geostationary orbits are orbits in the Equatorial plane having an orbital period of 24 hours, which causes the satellite to remain continuously over the same point on the ground. These

satellites provide the large synoptic views of cloud motion that are so useful in tracking storms, and are familiar on television weather programs. The most northerly or southerly latitudes cannot be seen from geostationary orbit and are only accessible by polar-orbiting satellites.

6. The angle of the sun to the Earth's surface, or "sun angle," controls the illumination of the scene. For some sensors, the sun must be nearly behind the satellite, producing a "flat," but high, illumination. In other sensors, the longer shadows associated with a lower sun angle are useful in analyzing topographic features.

7. M. S. Snow, *International Commercial Satellite Communications, Economic and Political Issues of the First Decade of INTELSAT* (New York: Praeger, 1976); J. N. Pelton and M. S. Snow, eds., *Economic and Policy Problems in Satellite Communications* (New York: Praeger, 1977); and D. D. Smith, *Communication Via Satellite, A Vision in Retrospect* (Boston: A. W. Sijthoff, 1976)

8. J. H. McElroy, J. Clapp, and J. Hock, "Earth observations: technology, economics, and international cooperation," in M. K. Macauley, ed., *Economics and Technology in U.S. Space Policy* (Washington: Resources for the Future, 1987). The concept of an international consortium for remote sensing is one of longstanding. See, e.g., K. P. Heiss, testimony in "Operational Remote Sensing Legislation," Record of Hearings of the Subcommittee on Science, Technology, and Space of the Committee on Commerce, Science, and Transportation, United States Senate (Washington: Government Printing Office, 1979); J. Grey and L. Levy, eds., *Global Implications of Space Activities* (New York: American Institute of Aeronautics and Astronautics, 1982); the series of editorials by J. McLucas in *Aerospace America*, namely "Whither Landsat" in January 1985, "Open skies a fresh challenge" in April 1985, and "Create a global Landsat" in July 1987. The concept of merging meteorological and land remote sensing satellites can also be found in P. M. Maughan, *Earthstar* (Washington: COMSAT, 1981) and J. L. McLucas and P. M. Maughan, "The case for Envirosat, *Space Policy*, 4:229-239 (August 1988).

9. SPOT (*Systeme Probatoire d'Observation de la Terre*) is the French land remote-sensing satellite system. The first satellite, SPOT-1, was launched in February 1986. Data are marketed worldwide by SPOT Image Corporation, a joint venture of CNES (*Centre National d'Etudes Spatiales*, the French national space agency) and numerous other organizations.

10. As an approximation of somewhat variable quality, spatial resolution can be assumed to be the size of the smallest object that can be seen by a sensor. The swathwidth defines the scene dimensions perpendicular to the ground track of the satellite. For the AVHRR, the spatial resolution is approximately 1.1 km and the swathwidth is 2700 km. The French SPOT satellite carries a sensor with a 10-meter spatial resolution and a 60-km swathwidth. The smaller the spatial resolution and the wider the swathwidth the greater the data rate and the more challenging will be the data processing. Swathwidth also affects the repeat coverage of the sensor. The

weather satellite sensor's wide swathwidth allows contiguous coverage, and twice-daily repeat measurements, while the narrower swathwidth of a land satellite sensor leads to 14 to 17-day repeat cycles.

11. S. Turner, "Opening the world's skies for mankind," *Space Policy* 1:357-362 (November 1985); B. Jasani, "Arms control and conflict observation satellites," *Space Policy* 1:363-368 (November 1985); L. Freedman and J. A. Schear, "International verification arrangements, Choosing the right approach," *Space Policy* 2:16-27 (February 1986); and F. R. Cleminson, "Paxsat and progress in arms control, Canadian research focuses on remote sensing applications," *Space Policy* 4:97-102 (May 1988)

John H. McElroy served previously as the Deputy Director of NASA's Goddard Space Flight Center, Assistant Administrator for Satellites of the National Oceanic and Atmospheric Administration, and Vice President for Technology of Hughes Communications Inc., a subsidiary of the Hughes Aircraft Company. He is presently Dean of the College of Engineering at the University of Texas at Arlington.

Mr. SCHEUER. Now we will hear from Jerry Caseman.

STATEMENT OF JERRY B. CASEMAN, HARRIS CORPORATION, ALEXANDRIA, VIRGINIA.

Mr. CASEMAN. Mr. Chairman, I appreciate very much the opportunity to be here today and first want to make it quite clear who I represent. I represent, first, Jerry Caseman. I do not represent Harris Corporation nor do I represent the Office of the Secretary of Defense where I left three years ago. My statement makes that very clear point and it was with some trepidation that I accepted Mr. Plummer's invitation to be here.

Clearly I've been involved in the issue of Landsat for about the last three to four years. I've had hundreds of dialogues with both government and commercial entities in this particular difficult situation and when I was asked to be on this panel it was a little bit of a question of why me?

Clearly my main background and reason to be here is as a former staff officer in the Office of Secretary of Defense working also as the leader of the Landsat interest of DOD and working directly for Mr. Don Latham who was then the Assistant Secretary of Defense.

Since that time, it will be three years ago this May that I left, I've been very heavily involved with the National Military Intelligence Association and in that role, primarily again because of my background in Landsat, I have tried to be a focal point as a member of the board of directors, and have organized at least two symposiums that have focused on some of the issues, difficult though they may be, involving Landsat.

Those evolutions brought me into extensive dialogue on this subject and some of the issues, both funding, the political issues as well, the technology. So even though clearly I am not a technologist—I'm a generalist with 20 years as an intelligence officer as well—I have some appreciation for some of the issues involved.

In terms of the comments I will have to say on the international viability of a consortium in particular approach to Landsat, I have some reservations. The reservations stem primarily from my background and looking at when did we have priorities and how did we exercise those priorities.

The U.S. government says many things and would like to do many things, but those vary from time to time. Even as we have varied on our approach to the funding requirements for Landsat. When we get into a sensitive political situation, we would like to say those are our assets we have direct access to them. We do the same with our meteorological program. Yes, we do share the data, it is available. But the fine lines do say that if they are in extreme situations of political sensitivities we may deny that data to other users.

There's both a pro and a con there. We would like to be able—we, carefully speaking as Jerry Caseman—the U.S. government would like to be able to join with others in achieving lower cost systems. That's true across many areas. We are already participating in other consortia as has been mentioned here today, but let

me give one example of that where we do not meet the same requirements.

One consortia I currently know of currently exists in Turkey in which a consortia there is trying to develop a U.S. power system. The guarantee that the government provided to consortia members was that there would be guaranteed sales. The U.S. government has not done the same thing with regard to their own participation of Landsat. We, on the counterpart, have offered that we may participate, we may not. We may provide data, we may not. It's a herky-jerky situation.

As Mr. Julyan said as well, you must have reliability of data and continuity of data. We have made it, marketing- wise, a most difficult situation for anyone to join us.

So as we begin to look at international consortia—

Mr. SCHEUER. For anyone to join us, what would their fears be?

Mr. CASEMAN. Their fears would be we indeed might have again this dualism. It is well known throughout the world that the United States is very sensitive to intelligence collection tools and interests. One of the challenges initially was that we might indeed consume more of the Landsat capabilities for DOD requirements and would give secondary consideration to commercial requirements. That was a consideration.

How soon we can convince others of our dependability on that issue is still yet the question.

In my statement, generic ability and to protect myself as well and recognize the very lateness that I got the fine invitation to be here, I nonetheless believe it's important to understand that we must make a positive step forward to join others in trying to drive the cost of remote sensing down. We have, once the data reaches the ground, some of the finest technology available in making that data have greater utility. Our value-added houses, I feel quite convinced, have the greatest capability that exists today.

And yet, on the other side, in terms of reducing the cost of our data capture facilities and our ground processing stations, I understand they currently are on the order of $10 to $20 million. So there are many things we could have done we have not done. We need to move forward, but also recognize the limitations we have put on ourselves.

I hope as well to be able to offer further comments on this subject.

[The prepared statement of Mr. Caseman follows.]

Testimony Statement for U.S. House of Representatives
Committee on Science, Space, and Technology

Subject: The Future of Landsat

Witness: Jerry B. Caseman

My name is Jerry Caseman, currently an employee of the Harris corporation as a Manager of Business Development activities within the Government Systems Sector. However,I need to emphasize to this committee that my presence to these hearings today is strictly as a private citizen, and that my opinions are my own and not necessarily those of my current employer, which I joined in January of this year, nor those of the Office of the Assistant Secretary of Defense, Command, Control, Communications and Intelligence, (ASDC3I) which I left in May of 1986. Having set forth this necessary caveat, I would now like to expresss my appreciation for the opportunity to offer testimony and support in behalf of this nation's Landsat remote sensing program, and hope that some of my previous experience in Landsat capabilities and issues may contribute to the important objectives set forth for these hearings.

The scope of my testimony here today, is significantly influenced by the fact that my Landsat and remote sensing experience has been acquired primarily as part of my government associated responsibilities during my service as a project and staffing officer for Landsat issues within the OASD-C3I office, under Mr.

officer for Landsat issues within the OASD-C3I office, under Mr. Don Latham. A second but major impact on my opinions offered is that for the past three years I have been heavily involved in government-industry symposia, which have focused on remote sensing technologies and Landsat policy issues, and thus brought me into contact with a broad range of the varied objectives and participants associated with this subject. My point here is that my experience, while that of a generalist, has enabled me to participate broadly in a representative portion of the salient arguments presented in behalf and against this nations Landsat remote sensing program. In my industry employment, initially with Eaton-AIL and currently with Harris, I have also had the opportunity to be aware of the application of modern processing technology to remotely sensed data and appreciate the "value added" results that can significantly increase the value and utility of coarse level data. It is within this context that I offer comments on the principal issues identified for this hearing.

Projections of Global Need for Remote Sensing Data: Although many more knowledgeable and technically astute witnesses will address this issue, I would like to offer a few observations regarding the likelihood of expanding requirements for remotely sensed data. First, as one analogy to the problem of harnessing technology to problems, I would like to call to mind the familiar complexities and frustrations of DOS commands and the heavy impact of a too hastily pressing "Enter" key on the office or home PC. Transition to "user friendly" word processors appeared to be a goal easily accomplished with only minor adjustment in skills required to operate the new system. In like fashion, finding and developing a robust commercial market for Landsat data looked to be a near term, achieveable goal. However, experience gained since the Land Remote Sensing Commercialization act of 1984, has shown that earlier projections for landsat data sales failed to anticipate several factors in the remote sensing market place.

One of the unanticipated factors was the oil glut and the decreased demand for landsat data from this heretofore major user of landsat data. Another predominantly important factor was the Challenger Shuttle loss which encouraged foreign competitors to vigorously pursue the share of remote sensing market which Landsat 6 might have garnered. Also unforseen was that the expanding capabilities and decreasing costs of personal computers would give rise to a much more sophisticated user of remotely sensed data. Today's information consumers are able to be much selective in data requested and can readily access data bases via

computer communications on an as needed basis. The ability to cross correlate data and bring multiple disciplines to bear on a given problem, has also made for a much more selective purchaser of data than our landsat marketeers first pursued. Though it is difficult to predict what the cumulative impact of some of these trends might be, the current strength of the French Spot Image system, and the emergence of other competitors such as the Japanese and the Soviet Union, makes it easy to predict an even more competitive road ahead. An EOSAT projection is that the worldwide remote sensing market could reach $6.6 billion between 1990 and the year 2000. A larger concern for us here today should be what might the US share of this market be, given the negative factors that we've allowed to accumulate around the future of our own system. Increased market share is seen possible if a more effective job is done in educating many third world and developing nations in the application of remote sensing technology to complex problems such as land use, resource management and protection of environment. Effective use of remote sensing requires broad understanding of several technologies, such as geographic information systems, data rectification and data base management. To date, very little institutionalized training in this discipline has been developed or made available. This would appear to be one immediate area in which the U.S. is capable of taking advantage of the extensive knowledge base acquired and developing further market potential.

Possible International Cooperative Arrangements: Due to the high costs of total system development for Landsat and similar function remote sensing systems, the consideration of shared launch costs and satellite buses with our international competitors would appear to offer significant cost-saving benefits. The difficulty occasioned with these cost-sharing approaches, however, may be conveniently divided into two major categories which make international agreements in remote sensing a long and involved process- the protection of proprietary technology; and the separation of economic opportunity from political sensitivity. In the first category, the United States for example, should be a reluctant partner to a joint remote sensing program if the price of participation included providing the best of our satellite on board processing technology. One would have to question, for example, what assurances a high-tech remote sensor vendor could expect that his technology would not migrate to other systems after the satellite integration vendor had maintained the payload system at the foreign countries launch site for several months. Could one country also delay or deny collection opportunities if sensitive national border situations were involved and the country affected happened to control the satellite's command and control communications system?

Some of these specific problems are addressable through the technologies of multiple access data links and multi-level security systems, yet the broader questions of how to maintain a

level playing field will take a much longer time for solution. Despite the difficulty involved, the United States should be taking a major pro-active role in bringing the benefits of today's remote sensing technologies to bear on critical environmental issues. Our current position as world leader in super computer technology could serve as a basis for effective negotiation with France and Europe in launch site access in return for assistance in developing improved data capture and processing facilities which would handle both Landsat and Spot Image remote sensor systems. A first step recommended would be to convene an International Remote Sensing congress, at which government and industry representatives could begin to identify areas most likely to yield cooperation and mutual benefits.

Mr. SCHEUER. Thank you very much, Mr. Caseman.

Congressman John Tanner of Texas—I'm sorry—Tennessee.

Mr. TANNER. Thank you, Mr. Chairman.

We have a saying in Tennessee, Mr. Chairman, that when the grand jury met in Tennessee back in the mid-1800s the population of Texas went up accordingly.

[Laughter.]

I apologize for being late. I just have one observation that I'd like to ask of Dr. McElroy if I might.

I was reading an article that appeared in Aviation Week and Space Technology in January of this year that was fairly critical, I suppose, in its treatment of the Earth Observing Satellite Company, EOSAT, and the fact that they were complaining rather forcefully about not being included in some talks that NOAA had with the French.

I guess my concern is is that this has been a continuing point of contention between our various agencies and how do we gain the confidence of the private sector in this country when our government policy seems to be at best inconsistent and at worst nothing more than crisis management? Does that question make sense to you?

Dr. MCELROY. Yes, sir. I almost wish that it didn't because you're entirely on target.

It is often embarrassing to me to see the contortions we go through in our policy making. We assert that we are in favor of the commercial development of space. There is only one significant commercial attempt being made right now, if we put aside the long-term exploratory research in materials processing and the occasional buying of a launch vehicle from the commercial sector.

The only activity that the U.S. government is purportedly attempting to transition to a commercial success is remote sensing. The amount of money involved is an insignificant fraction of our investment in space and yet we cannot seem to give a consistent direction.

I have sat in board of directors meetings in the private sector. I don't know how I would go to a board of directors with a proposition saying this is backed by the full faith of the U.S. government because right now all of our agreements are broken. We renege on every single agreement that we make with the private sector.

So it is almost an impossible situation for the private sector to cope with this because they, after all, are not in the business of simply burning up large quantities of money to the advantage of the U.S. government.

Mr. TANNER. I guess this would be a question specifically with regard to this article. Do you think EOSAT's position as it relates to them not being included apparently with some of these talks between NOAA and the French, do you think their position is justified or should they be, as a government contractor, included in policy decision making?

Dr. MCELROY. If we are going to treat EOSAT as our intended designee to conduct remote sensing and we're going to conduct negotiations which strike at the very heart of their business, then clearly they must be included.

Mr. TANNER. One other question if I might, Mr. Chairman.

We were in, I suppose, this room a week or so ago and there was controversy regarding the FSX--not in this room but downstairs. But there was considerable controversy about a transfer of technology with the agreement with Japan from this country to that country as it relates to FSX.

Would you comment on the same fears were they to be voiced here as it relates to our international cooperation with the French of Japanese or others?

Dr. McElroy. Being only a short distance from Fort Worth, I hear a lot about the FSX in our news.

I will simply point to the example of the INTELSAT and INMARSAT. Certainly communications satellite technology is sensitive technology. It falls under all of the arms control regulations, and yet we seem to be able to cope with it there.

If you look around the world, if you look at the Japanese technology, the French technology, the Soviet technology, it's not clear which way technology transfer is going to go, frankly. So I think that, while that must always be a concern to us, if we could solve it in other forums and if the other countries are at least evidently as capable as we are, then the technology transfer cannot be a show stopper.

Mr. Tanner. Thank you, Mr. Chairman, for allowing me the time.

Mr. Scheuer. Thank you, Congressman Tanner.

Dr. McElroy, could you respond to the concerns that you've just heard Jerry Caseman express about joint ventures? His first concern the loss of control over the satellite and the second is the concern of foreign governments about the role that our defense department would assume and the possibility that they would absorb or gobble up a great deal of the time and resources of the satellite.

Dr. McElroy. Yes, I'd be glad to. The concerns are legitimate. They must be addressed. The only controversy in my mind is how much of a compromise you have to make in addressing those concerns.

As far as the resources of the satellite being gobbled up, today at least we have excess resources. As we proliferate ground stations around the world, then the issue of use of resources becomes less and less significant. Where that most frequently is encountered is in the allocation of tape recorder capability.

So I believe that those are problems which certainly are serious and must be addressed, but are solvable.

Mr. Scheuer. Dr. McElroy, in previous testimony before this committee, which we appreciate and value very much, you observed that the first step toward resolving our dilemma is to eliminate the ambiguity in support of our national designee, EOSAT.

Do you still maintain that view? Do you feel that EOSAT should be involved in U.S. government discussions with other nations regarding consortia in remote sensing? I would have to footnote that by saying in recent discussions between the National Oceanic and Atmospheric Administration and the French, the EOSAT was not represented and not involved.

And if we were to take an approach to remote sensing of adopting a kind of an INTELSAT format, would you recommend that we

scrap our contractual relations with the EOSAT or would they be designated the U.S. lead agency?

Dr. McElroy. First of all, let me note that I carry no brief for EOSAT, but there is an issue of fair play here that is a little bit difficult for me to cope with; namely, you take an entity and you put them through a tough competitive process and they come out the winner of that process, and then you say, well, we're going to start over again.

Now I can understand politically it might be necessary to start over again and, of course, I, as everyone, would accept that. I would hope that in whatever process that we go through that EOSAT would have a major voice and have recognition of the contribution that it's made to try to live in this difficult environment.

Mr. Scheuer. Dr. McElroy, I would disagree with you that there might be a political reality for excluding EOSAT, apart from demonstrated incompetence or negligence or some other truly negative characteristic of their performance.

I agree with you that once having asked them to go through an expensive competitive process that, assuming that they have won fairly and assuming that they have performed professionally and adequately and that no real questions have been raised about the quality and the professionalism of that performance, then I would say that I would find it unacceptable and objectionable if political considerations were raised to ease out the American presence, so to speak, that competed at great expense, were recognized and performed satisfactorily.

What kind of political considerations could possibly dictate easing them out, apart from considerations of the national interest? And it seems to me that it's a barely rebuttable presumption that if they won it fair and square and if they perform professionally, that by every test not only of fairness but of our national interest, they should continue to be the American representative. And I say political considerations be damned. Am I wrong? National interest considerations are what should prevail. And absent any indication that they aren't performing adequately according to the contract and according to high professional standards, absent any indication that their performance has been inadequate and absent any indication that they didn't win it fair and sqaure, it seems to me that the national interest would determine that they continue to be our representative. Am I wrong?

Dr. McElroy. I happen to agree with you. The context of my response was that, in my view, if you merge the weather satellite functions with the land remote sensing and create an Earth observations entity, then you are so broadening the scope of the activity that then the issue of recompeting for that total activity might be raised. I could imagine that coming up in the Congress, for example.

Mr. Scheuer. I quite agree with you, but that's not a political consideration. That is a substantive national interest consideration. Then the question, it seems to me, is how do you factor in in a fair way and in a way that is consistent with our national interest the fact that EOSAT has performed satisfactorily and thus in such a percentage of the total mission now, do you release them and try to get some other entity to fill the whole new mission, the rather sub-

stantially increased mission, or might there be a consortium of American groups? Might you want to add another American entity to EOSAT to fill out the new element, the new component that you have added to the mission? Is that a fair, reasonable way to put the question?

Dr. McElroy. Yes, sir. I think adding entities would be certainly a plausible step. I can imagine a number of entities who could contribute to the development, as you have stated. My concern is that we do treat an entity fairly and I say that not only from a perspective of the local issue of Landsat. The U.S. government, if it's going to have a reasonable relation with the private sector, simply has to be a good business partner. And I don't believe it has been with EOSAT.

Mr. Scheuer. A good business partner and a reliable business partner, and there have been too many instances in the past where government has performed in such a way that had that behavior been produced by a private sector group they would have been raked over from hell to breakfast and accused of immoral, unethical, perhaps even illegal behavior. But because it's a government entity, from the point of view of morality and ethics and fairness, they get away with bloody murder and nobody brings them up to the standards that they systematically apply to the private sector.

Is that a fair statement?

Dr. McElroy. Yes, sir. I couldn't say it better.

Mr. Scheuer. Now I don't believe that we ought to throw EOSAT any cream puffs and in any sense accept any deviations from absolutely proper and professional behavior on their part, but they are entitled to have the government live up to the same standards of fairness and responsibility that they are being held up to and it seems to me that, absent some real failure of performance on their part, wrongdoing, negligence, incompetence, whatever, that there ought to be a barely rebuttable presumption that they would be entitled to participate in the future.

Now I can envisage as a theoretical matter—when you've added to the mission of the remote sensing satellite that you've just discussed, I can imagine as a theoretical matter that some American capability or presence might loom up that is capable of providing the entire range and breadth of the new mission, including the part that you've added, and that they would be clearly, demonstrably superior to EOSAT, that they could handle the whole thing themselves. And in such a case, I can understand our government taking a rather tough businesslike point of view and saying, look, these are altered circumstances, we've expanded the mission, we've got a new entity here that is demonstrably capable of handling the entire new mission, you're not; and therefore we're going to have to excuse you from further participation, even though that may seem fairly hard-nosed and unfair.

Well, as President Kennedy said, life isn't fair. Life is unfair. And conceivably I could conjure up a theoretical set of circumstances whereby EOSAT might be left out in the cold.

But absent such an overwhelming new set of circumstances with an enlarged mission and some new entity coming from somewhere that was clearly capable of meeting the entire new length and breadth of that enlarged mission—absent such a circumstance, it

seems to me that EOSAT has a moral and ethical and probably—well, I don't know if they have a legal right to continue their participation, but it seems to me that if we can't treat a private sector company that has had a major investment in competition, has met the test of competition, and then has met the test of operational performance successfully from every point of view of professionalism, if we can't treat that company of that kind fairly, then the whole business of government-private sector collaboration comes under real question.

It seems to me that, to repeat your phrase, that if government can't treat private enterprise fairly and decently and ethically and morally, in addition to legally, if they're going to be looking for fine print to perpetrate real unfairness, it seems to me that the whole future of government-private collaboration comes under a real cloud.

I just wonder how we can expect the private sector to risk its talent, risk its time, and risk its resources, when they have no justification from the point of their stockholders in assuming that they are going to meet with fair play down the line. Is that a fair statement?

Dr. McELROY. Yes, sir. The private sector will not cooperate in such arrangements.

Mr. SCHEUER. Mr. Caseman, on page 5 of your testimony, you discuss the possibility that a satellite company could lose some of its technology—by that I mean it would seep out to people that it didn't expect it to seep out to—lose it in a security sense—if a satellite was stored at a foreign launch site, is it realistic to assume that if the U.S. demanded that guards be stationed at this site so that the theft of technology couldn't occur, that we could rely on that security provision to protect our technology?

I notice that that's what the government has assured the Congress and the American public that that's how they would protect this new joint enterprise with the Japanese with the FSX, that they would have guards stationed about so that there would be no possible leakage of technology which we didn't want to leak.

I'm not asking you to express an opinion on that subject, which I have some reservations about, but can you express an opinion as to whether stationing guards around a satellite launch station could protect the technology that we did not want to give away or have seep away?

Mr. CASEMAN. I would definitely have to say that stationing guards would appear to be insufficient protection to potential technology capture. In terms of data streams which are coming back from satellites in an unsecured, unprotected mode, that would also expose potential technology we are currently using in that system.

Most of my concern—and that was a bit of a stopping horse to bring out an issue there—there will be sensitivity and reluctance of the highest levels of sensing development houses in this country to want to offer their technology to be assembled and put together in another country to be exported and potentially used in another area.

Companies that I've been associated with—this is my second company here—clearly always have proprietary concerns—how

soon does my best and newest technology gain share of the marketplace before someone else can take advantage of it?

Mr. SCHEUER. Excuse me. Describe what you mean by "take advantage of it."

Mr. CASEMAN. Take advantage means gaining a fair share of that marketplace, a return on investment, a return on all the expensive research and expensive R&D done to produce that technology that makes it attractive.

Mr. SCHEUER. Now what you're talking about is technology that becomes public in effect which is taken advantage of by a foreign government legitimately where they have perhaps a very rapid ability to implement it in practical terms. You've expressed reservations about that.

How about the reservation that it will leak and be appropriated by a foreign government by stealth, not by consent, and will be used to compete unfairly with an American entity in that fashion?

Mr. CASEMAN. I can't say conclusively and specifically how far that might go. I can say that there are certainly techniques by which one can capture technology and seldom, if ever, is technology protected by guards. It is protected by sensitive things of communications security and denial by sensitive sensors, like the Tempest problem, for example. So it's that arena where if we allow and encourage all industry to put our best technology through a consortium approach, through Landsat programs, there will be some limitations and constraints. We will not find many industries willing to go very far in that direction.

Mr. SCHEUER. The DOD has approved the shipping of three U.S. communication satellites to China for launch. Do you see any security reason or any reason of competitiveness why, if we cooperate with China, we couldn't cooperate with the French of the Japanese?

Mr. CASEMAN. First, let me state that I do not speak for the DOD. I do work and meet with those folks from time to time where I used to be in that office. And clearly I know we have cooperative agreements, but we also have constraints built around that.

Again, the more generic we keep a system and the more we allow it to be an open source of data processing on the ground, in those areas are the greatest areas for cooperation.

In terms of going beyond that with our technology, there are more constraints there than are spoken and I'm not the one to speak for that. That's a question that should be referred to the DOD side of the house.

Mr. SCHEUER. Mr. Caseman, I respect your constraints and we all do. Mr. Caseman, what do you see as the primary problem with the concept of an international remote sensing consortium? Is it the loss of control over the data, guards notwithstanding? Is it potential theft of technology, guards notwithstanding? Is it loss of control over the satellite? Is it the whole complicated business of who is going to own what in terms of the data and who is going to be allowed to commercialize what and under what circumstances? What do you see as the impediments to joint international remote sensing?

Mr. CASEMAN. I see a main constraint to be priorities and prerogatives. Clearly most of that touches on areas of political sensitivity.

It touches some as well, as I mentioned, on the technology side. But each country has its own agenda and that agenda varies again by what the situation is in the world at any given time.

If it's a situation in which there are border disputes and border sensitivities, you can be assured that we will have our own agenda as will other countries perhaps with their own remote sensing system.

If we propose to join a consortia approach to remote sensing with increased resolution particularly, 10-meter currently for SPOT and going down to 5-meter, a lot of utility in terms of application of that data to political and military situations will be obtained.

Countries using that data will also be sensitive as to how much do we share. If I have and know that I can use an open sky remote sensor to verify activity that's going to be a threat to my country, I will certainly be the first to want to claim the rights to that data or to deny others that data. That's going to be a very difficult thing to untangle as we begin to have our initial dialogue, particularly if I'm the country that has the main command control link to that satellite. It has to exist somewhere. Control links can be multiple in part and allow multiple access, but that itself would be a very contentious issue.

If I'm a highly developed country as well and have sophisticated techniques to deny or to take out a command control link, certainly a Third World country participant will say, "I'm not on an even playing ground."

Those are issues that have to be addressed I think very early on in terms of how much true openness can our government and other governments achieve. Those are the kind of issues I'm trying to raise as being important.

Mr. SCHEUER. My final question is to the whole panel and then, Congressman, I'm going to yield to you for any last questions you may have.

Who would you say is ahead in satellite or sensor technology? The Russians, the Japanese, the French, or the Americans? What does the current and the long-term competitive situation look like?

Dr. MCELROY. Let me start with that and then let Mr. Caseman respond as well.

It is my firm belief that today the United States is well ahead, particularly if you include in your equation the total military capability that we have. I believe that we are ahead probably with a lead of quite a few years.

Now the issue then becomes how much of that technology is needed by a viable commercial entity and how much is really enough to get commercial viability. It is my opinion that the French and the Japanese and the Soviets all have a commercially viable capability, even though if you took the total picture their total capability in remote sensing would be less than ours.

Mr. SCHEUER. Mr. Caseman?

Mr. CASEMAN. I would agree with that completely, that we certainly have the highest level of technology available, but it would not be a constraint to our potentially being commercially viable.

The area I see we have not promoted enough is the superior knowledge of processing that even takes course data and makes it much more valuable. In terms of things I have seen in terms of dis-

play, in terms of merging of data, I think our technology there is equal to any else in the world. But in terms of making people understand the power of that, we have failed to do that.

Across the entire commercial sector, I understand there is only one two-week orientation course that tries to explain what the benefits of remote sensing might be of Landsat systems. That's a shame on us to the highest degree and something we certainly should bring into the universities, asking for assistance.

Mr. SCHEUER. Let me yield to Congressman Tanner.

Mr. TANNER. Mr. Chairman, I thank you.

Just to follow what your line of questioning was, where do we go from here, in your opinion? I understand the National Space Council will have a report maybe at the end of this month as it relates to options and so forth. Both of you have said that we ought to move ahead internationally once we have a secure footing in this country. How do we get that secure footing in this country I guess is my question.

Mr. CASEMAN. I'll take a first try. The first try is one borne of frustration—the desire of myself to respond. In terms of the multiple voices we have had on this issue from so many different agencies of our government and the fact that no one of those has been consistent. Clearly, the testimony we heard from Mr. Julyan is one that shows that the country of France at least is very consistent as to where they want to go. They have indeed made hay while the sun shone with regard to our limitations with our own remote sensing program. They make no apologies for that. At the same time, they offer to us lessons we should have learned. Make your mind up where you're going and then decide the best direction to proceed. Do not change from one day or one budget year to the next.

So first we have to establish a consensus in terms of the U.S. government of the value of additional things that the system does for us as a government. Then, as well, I also heartily subscribe to the fact we must say, how do we maximize the commercial benefits so a firm who has invested and has put the effort forward to be this government's U.S. representative in the remote sensing world, EOSAT, indeed is not penalized, as they have been for the past four or five years.

So let's first decide where we're going and how to best optimize the system and put our best talent to that problem.

Dr. MCELROY. Based on the Vice President's decision to at least sustain Landsat for a brief period of time, I am hopeful that the National Space Council deliberations will be fruitful and lead to the conclusion that we should not throw away about half a billion dollars of hardware which is sitting up there doing productive work for us.

Whether that will come out, I don't know. In the year before the inauguration, Brent Scowcroft and I co-chaired a space policy study in anticipation of a new administration coming on-line. One of the recommendations we made in that space policy study—the key recommendation indeed—was that there has to be a central focal point for civil space activities to reduce the number of voices which can in a disruptive way contribute to turmoil but not to decisions.

We recommended that such a charter be given to the NASA administrator as a way of attracting a very competent person into that role. That might be a way to do it.

Certainly when you have Commerce, Transportation, Energy and all of the others being able to raise objections but not act, it's not a very constructive situation.

Mr. TANNER. So you all recommend that the NASA administrator be given the lead?

Dr. MCELROY. Yes, sir. What we recommended was that someplace in the government there be one person who is in charge of civil space to bring those decisions to a coalesced form and present them to the President, and we felt the most logical person would be the NASA administrator. We also felt that a fairly restricted membership on the National Space Council might help there as well with having the NASA administrator representing others rather than having them sitting at the table.

Mr. TANNER. Thank you, Mr. Chairman.

Mr. SCHEUER. Thank you. One last question to both of you.

If you were advising Vice President Quayle, who is taking a remarkable leadership role in this whole matter, would you advise him to proceed with discussions and negotiations on the creation of an international space remote sensing capability with perhaps Japan and France and the Russians? Would you counsel him to go for it in creating an international consortium or would you advise him that that's a hazardous, questionable route?

Dr. MCELROY. With the caveats I've stated that we have our own house in better order than it is today, I would.

Mr. SCHEUER. Mr. Caseman?

Mr. CASEMAN. I would say in particular that the first question be to get your own house in order and to bring the best of our technology and our management expertise to this problem. We've allowed it to be handled by a very small and changing elements of our government and we don't have a common voice. We don't have commitment. That has to be achieved first.

Mr. SCHEUER. We don't have commitment. That's not a problem of the space community or the business community. That's a problem in government. That's a problem of the Congress and the executive branch. There has to be a commitment there and there has to be far better management in government of the whole question of assured, long-term, continuous and systematic funding and support of the venture. It seems to me this is a problem of government administration that they could take up at a Harvard Graduate School seminar—the lack of commitment, the lack of competence in management of this space venture and the whole business of managing it on this on-again-off-again, hit or miss basis. That is pure management incompetence on the part of government and there's enough blame to go around between the executive branch and Congress.

Can we all agree on that?

Mr. CASEMAN. I certainly would.

Mr. SCHEUER. All right. It's been a very interesting session. We thank you very much. There's a roll call vote on now. So we will excuse you with gratitude and we will suspend for about twelve or fifteen minutes before we take on the last panel. Thank you very, very much.

[Recess.]

Mr. SCHEUER. The subcommittee will reconvene and we will ask Mr. Michael Meier, Dr. Robert Brammer and Mr. John Egan to come to the witness table.

We apologize for the lateness of the hour with which we've reached this panel. I hope you've been here for the two preceding panels and you'll understand why we stretched our timeframe to the limits. They were both very, very interesting.

The third panel will be on Landsat marketing studies. Michael Meier, Vice President of KRS Remote Sensing; Dr. Robert F. Brammer, The Analytic Science Corporation, TASC; and Mr. John Egan, The Egan Group.

We will ask you to stick to five, six or seven minutes. I'm sure that we will have some questions for you when you're finished. Your full prepared testimony will be printed as you have prepared it at the point in the record at which you testify.

So we will start out with Mr. Michael Meier.

STATEMENT OF MICHAEL MEIER, VICE PRESIDENT, KRS REMOTE SENSING, LANDOVER, MARYLAND.

Mr. MEIER. Mr. Chairman and other distinguished Members of Congress, KRS Remote Sensing is pleased to provide testimony before the joint Subcommittees of the U.S. House of Representatives' Committee on Science, Space and Technology.

We have submitted our written testimony in the form of the executive summary of the study for an advanced civil Earth sensing system delivered to NOAA nine months ago in August 1988. The complete report consists of four volumes, including a classified annex furnished separately dealing with specific aspects of the Department of Defense markets and technology.

Joining KRS in this study were three companies: Peat, Marwick, Main & Company; Geodynamics Corporation; and Science Applications International Corporation. The findings presented here represent the cumulative knowledge of 80 contributing professionals from our team of four companies.

The intent of the KRS study was to assess the commercial viability of an advanced civil Earth remote sensing system presumed to be launched in mid-1995 returning data in early 1996.

Financially speaking, providing a free launch or underwriting insurance or any of the 20 financial options developed during our study still represent a cost to the U.S. government no matter which agency is the provider or which financing option is chosen—consortium or 100 percent U.S. ownership.

We were to recommend for consideration by the U.S. government options for the system that minimize U.S. investment, including end-to-end consideration of the entire space and ground system, ranging from technology development to sale of value-added services and products.

In our study we first analyzed the worldwide civilian and DOD markets. Our team then identified technologies required to satisfy market demand and means for stimulating new or increased demand. The best and newest technology is not necessary to solve market demand.

Our team performed financial analyses of 10 widely varied technical sensor ownership options versus worldwide civilian and DOD markets. Each of the 10 space segment ownership options failed the first test of commercial viability since revenues fell short of investment in every case. The least costly options caused commercial space segment investors to lose approximately $100 million when compared to any other three-year investment alternative that would return 40 percent.

Our conclusions are as follows:

The space segment cannot be commercialized during the present century.

The combined (system which includes end-to-end consideration of the entire space and ground system, ranging from technology development to sale of value-added services and products,) also cannot be commercialized during the present century.

The ground segment component, excluding the ground receiving stations, can undergo complete and profitable commercialization during the 1990s.

U.S. government investment in the space segment and domestic ground stations is necessary. The investment required can be markedly reduced through an international partnership of some kind.

The U.S. government, excluding the Department of Defense, will continue to be the largest market segment through the 1990s. New emerging markets such as topographic mapping, waste management, simulation, engineering and construction, and utilities will contribute significantly to future demand for remote sensing products and services. Specifically, higher resolution sensors, both spatially and spectrally, are required to satisfy these new markets.

Our recommendations are based on our requirement to recommend options which minimize cost to the U.S. government. We offer an option offering the highest benefit ratio for relatively low U.S. investment and outstanding commercial promise for consideration by the U. S. government.

The sensors for the space segment sensor suite consist of a stereoscopic, multilinear array offering 5-meter resolution, an enhanced thematic mapper, and a moderate resolution broad swath radiometer. Typically, these sensors have one kilometer resolution versus five meter resolution.

Our ownership recommendation is a controlling 40 percent U.S. government ownership share in an international space segment consortium.

In addition, we recommend that the United States establish a strong advocate entity within the U.S. government responsible for system level funding decisions, policy formulation, and management oversight at the overall system level.

In summary, we were asked to assess the commercial viability of the system and recommend for consideration by the U.S. government options for the system that minimized U.S. investment. It is the stated policy of the United States to encourage the development of commercial systems which image the Earth from space, competitive with or superior to foreign operated civil or commercial systems. In a changing global economic market, the United States and the international community can benefit from effective

United States implementation of a long-term global Earth remote sensing strategy.

This concludes the summary of our written testimony and we welcome questions from the committee.

[The prepared statement of Mr. Meier follows.]

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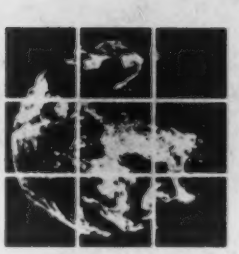
STUDY FOR AN ADVANCED CIVIL EARTH REMOTE SENSING SYSTEM

KRS REMOTE SENSING
A Kodak Company

Volume 1

A Report to the U.S. Department of Commerce

Study for an Advanced Civil Earth Remote Sensing System



VOLUME I.
Executive Summary

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National Oceanic
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Administration
11420 Rockville Pike
Rockville, Maryland

by:
KRS Remote Sensing,
A Kodak Company
1200 Caraway Court
Landover, Maryland 20785

KRS
REMOTE
SENSING
A Kodak Company

This report to the U.S Department of Commerce presents the results of a comprehensive study of options for an Advanced Civil Earth Remote Sensing System (ACERSS) to follow Landsat 6.

"The development of this report was conducted under contract with the Department of Commerce to obtain an independent analysis for the Government to consider in preparing its action plan for an Advanced Civil Earth Remote Sensing System. Any opinions, findings, conclusions, or recommendations for the Government to consider that are expressed in this report are those of the contractor and do not reflect the policies or approval of the United States Government."

FOREWORD

This report to the U.S. Department of Commerce presents the results of a comprehensive study of options for an Advanced Civil Earth Remote Sensing System (ACERSS) to follow Landsat 6. Landsat 6 is currently planned for launch in 1991. It is presumed that ACERSS will be launched in mid-1995 and begin to return data in early 1996.

The study approach followed three basic steps:

- Projection of worldwide market demand for raw data and value added information products;
- Identification of technical and implementation options for satisfying this demand;
- Determination of the commercial viability of these options.

In support of this study, KRS Remote Sensing commissioned several investigations focused on key topics. These contributing studies (and the subcontractors performing them) were:

- Survey of civilian markets (Peat Marwick Main & Company);
- Survey of Department of Defense market (Geodynamics Corporation);
- Assessment of sensor and data processing technology (Science Applications International Corporation);
- Assessment of spacecraft and launch technology (Science Applications International Corporation);
- Study of financing options (Peat Marwick Main & Company).

Results from these focused studies have been consolidated into two support volumes. Accordingly, the overall organization of this final report is:

Volume I: Executive Summary

Volume II: Market and Financial Assessment

Volume III: Technology Assessment

A classified annex dealing with specific aspects of the Department of Defense market is furnished separately. Although the remote sensing industry includes analysis of observations of the Earth's surface made from aircraft, this report deals only with space-derived data and the satellite portion of the industry.

CONTENTS

ABSTRACT AND SUMMARY 6

A. OVERVIEW 8

B. CONCLUSIONS 10
- Projected Market Demand 10
- Commercialization Potential 10
- Case for Continued United States Participation 14

C. TECHNICAL OPTIONS 16
- Performance Requirements 16
- Sensor Options 16
- Market Driven Sensor Assessment 17

D. IMPLEMENTATION OPTIONS 20
- Case for International Ownership 20
- Viable Options 21
- The Implementation Options Compared 24
- Development and Negotiation Schedule 25

E. MANAGEMENT OPTIONS 26
- Private Sector Management 26
- Government-Industry Partnership 26

F. POLICY OPTIONS 27
- Restructuring of System Costs 27
- Reduction of Business Costs 29
- Increase of Revenues 30
- ACERSS Advocate to Provide Single Point of Conduct 31

G. RECOMMENDATIONS 32

APPENDICES
1. MARKET SEGMENT DATA 34
2. SENSOR MARKET WEIGHTING 36
3. NET PRESENT VALUES 38
4. TERMINOLOGY 40
   - Key Concepts and Terms 40
   - Acronyms and Abbreviations 40
5. FURTHER READING 43

FIGURES

1. Space and Ground Segments 9
2. Space Segment Revenue Shortfall 11
3. Growth of Value Added Market 13
4. Combined System Revenue Shortfall 14
5. Qualitative Assessment of Current Technology 17
6. Schematic Illustration of Market Driven Technology Assessment 19
7. International Remote Sensing Missions 21
8. Comparison of Space Segment Implementation Options 24

TABLES

1. Projected Total Revenues 12
2. Market Driven Technology Requirements 16
3. Sensor Types 18
4. Case for International Ownership 22
5. Financial Summary of Ten Space Segment Implementation Options 23
6. Projected Growth in Civil Markets 34
7. U.S. Government Market Profile, High Growth Scenario 34
8. Private Industry Market Profile, High Growth Scenario 35
9. Market Weighted Score for URV/IR Sensor Type 36
10. Market Weighting of Data Products 37
11. Commercial Viability 39

ABSTRACT AND SUMMARY

Intent. The KRS study was intended to: (1) investigate technical and U.S. Government policy options for an Advanced Civil Earth Remote Sensing System (ACERSS), taking into account market trends, technology, conditions for private investment, and opportunities for international cooperative partnerships; (2) assess the commercial viability of ACERSS; (3) evaluate options for ACERSS in terms of required U.S. investment and projected revenues to the U.S.; and (4) recommend, for consideration by the U.S. Government, options for ACERSS that minimize U.S. investment.

Approach. Commercial remote sensing must be market driven, rather than technology driven. A comprehensive study must consider the entire space and ground system, ranging from technology development to sale of value added services and products. KRS (1) analyzed markets worldwide for raw data and value added products to establish revenue projections; (2) identified technologies required to satisfy market demand and means for stimulating new or increased demand, and (3) performed financial analyses of ten widely varied sensor/ownership options for the ACERSS space segment to determine required investment, projected revenues, and ratio of revenue to investment ("benefit ratio").

Assumptions. (1) The ACERSS space segment consists of launch vehicle, sensors, spacecraft, and satellite command, control, and communications. (2) The ACERSS ground segment consists of ground receiving stations, data analysis, interpretation, marketing, sale and distribution of the information thus derived. (3) Costs of domestic ground stations are borne by the owner/operator of the space segment. (4) Costs of foreign ground stations are borne by foreign governments; ACERSS access fees are collected by the space segment owner/operator. (5) Space segment options assume polar orbit and 3 year mission lifetime. (6) Ratio of U.S. space segment revenues to U.S. space segment investment is an appropriate measure of benefits to the U.S. from Federal investment in the ACERSS space segment. (7) Markets for remote sensing data and data products (including new, emerging markets) will evolve independently from 1988 base year levels in response to market stimulation and introduction of new technology. (8) It is in the U.S. national interest to maintain technological leadership in civil Earth remote sensing from space. (9) Inflation will proceed at 5%/year for both costs and revenues. (10) Market projections were aggregated into three market growth scenarios: (a) Low growth (5%/year)—no market stimulation; continuation of present market; no real growth. (b) Medium growth (12%/year)—stimulation of present market, but without introduction of new technology. (c) High growth (about 20%/year)—stimulation of present market, together with introduction of new technology in the 1990s in response to market demand.

Conclusions. The primary conclusions follow from a comparison of the market growth scenarios with typical annual costs for a Landsat-type system: (1) The space segment cannot be commercialized during the present century. Even in the high growth scenario, with 100% global market share, revenues would not cover costs until about the year 2000. (2) The combined system—space plus ground segments—cannot be commercialized during the present century. (3) The ground segment (except the ground stations) can undergo complete and profitable commercialization during the 1990s. (4) U.S. Government investment in the space segment and domestic ground stations is necessary for U.S. participation in ACERSS. The investment required can be markedly reduced through an international partnership.

Additional findings follow from the market and technology studies: (5) The U.S. Government (excluding DoD) will continue to be the largest market segment through the 1990s. (6) The present market survey supports earlier predictions of a strong commercial remote sensing market in traditional applications. (7) New, emerging markets, such as topographic mapping, waste management, simulation, engineering and construction, and utilities will contribute significantly to future demand for remote sensing products and services. (8) During the 1990s, nearly all commercially important market demands can be met by combinations of five sensors: ultrahigh resolution stereo Multispectral Linear Array (MLA); high resolution Enhanced Thematic Mapper (ETM); a moderate resolution radiometer, such as the Sea Wide Field Sensor (SeaWIFS); synthetic aperture radar (SAR); and a low frequency microwave radiometer.

Options. Ten sensor/ownership options for an ACERSS space segment were studied. The options combine a selection of sensors with a choice of: (1) 100% U.S. ownership, (2) a controlling 40% U.S. ownership share in an international consortium, or (3) a 50-50 bilateral partnership. The first three options—flight of SeaWIFS on a "Lightsat" and reflights of the Landsat 4 sensors—involve no new sensor technology and were included to provide a baseline for comparisons. Six options involve advanced sensors, such as a 5 meter (m) resolution stereo MLA or a SAR. A tenth option provides for an advanced commercial sensor suite on the polar orbiting platforms of the planned Earth Observing System. Low investment options having high benefit ratios were identified. An option offering the highest benefit ratio, a relatively low U.S. investment, and the most commercial promise is recommended for consideration by the U.S. Government.

Recommendations. *Sensors:* an ACERSS sensor suite consisting of (1) a stereoscopic MLA offering 5m resolution; (2) Enhanced Thematic Mapper; and (3) a moderate resolution, broad swath radiometer similar to SeaWIFS.

Ownership: a controlling 40% U.S. Government ownership share in an international ACERSS space segment consortium. Advantages over total U.S. ownership: (1) reduced U.S. Government investment; (2) increased market share of international space segment revenues; (3) for all nations involved, freeing of funds for other high-priority investments; and (4) selective exploitation of diverse international assets and technical strengths. Disadvantages: (1) less than 100% guarantee of data availability to U.S. users; (2) difficulty in forming consortium to meet 1995 launch target; and (3) necessity to develop multinational command, control, and data processing procedures.

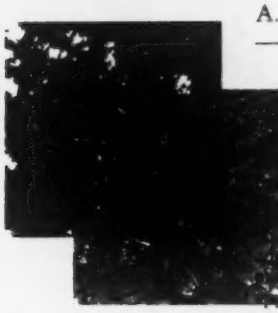
Establishment of a strong ACERSS advocate within the U.S. Government to provide a single point of contact for ACERSS funding decisions, policy formulation, and management oversight.

Continuation of present experiment for private sector management of the space segment and domestic ground receiving stations through prompt initiation of a competitive process for ACERSS management.

Immediate steps to develop a 5m stereoscopic MLA responsive to the commercial market in time for spacecraft integration by 1994.

Initiation of efforts to negotiate an international agreement for ownership of the ACERSS space segment and ground stations.

A. OVERVIEW



The possibilities of ACERSS commercialization are examined in Section B. Following sections present market driven technical sensor options (C), sensor/ownership implementation options (D), space segment management options (E), U.S. Government policy options (F), and recommendations for U.S. Government consideration (G). Five appendices provide details and supplementary information.

8

s part of the process of funding Landsat 6, the United States Congress cted the Department of Commerce to conduct studies for an advanced em that would follow. In response to that Congressional directive, the artment of Commerce commissioned this study of the technical, ncial, management, and policy options for an Advanced Civil Earth ote Sensing System (ACERSS).

he underlying point of view taken by this study is that the design of nced systems should respond to the demands of the most active kets forecast for those systems in the future. This market driven proach will place remote sensing on a commercially successful basis sooner than would the technology driven approaches followed in the past.

The study treats the space segment of an advanced system separately from the ground segment (Figure 1). The space segment consists of launch vehicle, sensors, and spacecraft, together with satellite command, control, and communications. The ground segment consists of the ground receiving stations and the value added industry, which provides data enhancement, analysis, archiving, and interpretation of remotely sensed information, and markets, sells, and distributes the resulting information products. Foreign ground station fees are conventionally collected by the space segment owner/operator and are thus counted as revenues to the space segment.

The report first presents conclusions (Section B) concerning ACERSS commercial possibilities during the 1990s and the significance of continued United States participation in such a system.

It is concluded that only the ground segment (exclusive of ground stations) will be commercially viable during the 1990s. Therefore, the study examines ways to increase space segment revenues and decrease space segment costs. By far the most effective way to increase space segment revenues is through design of a system that meets commercial needs, thereby increasing the likelihood of vigorous market growth through the expansion of present markets and the creation of entirely new market segments. Market requirements for sensors are discussed in Section C, which presents the most viable technical options.

New technology will not reduce space segment costs significantly. Rather, the most significant cost reductions for the United States would result from international ownership of the space segment. The advantages and disadvantages of various U.S. ownership options are discussed in Section D. That section also describes the costs for implementing possible sensor suites, the revenues that would be anticipated from each, and the resulting ratio of revenues to investment (the "benefit ratio") under various ownership options. Evaluation of these results shows that if there is to be U.S. participation in an advanced system, some form of U.S. Government investment is necessary.

Given Government ownership of all or part of the space segment, there are several options for private sector participation. These could take the form of a government-industry financial partnership or a continuation of private sector management, as described in Section E.

Changes in policies followed by the U.S. Government may have a major impact on the commercial prospects for an advanced system. Current U.S. national space policy states that "...The United States Government shall not preclude or deter the continuing development of a separate, nongovernmental commercial space sector," and that "Governmental space sectors shall purchase commercially available space goods and services to the fullest extent feasible and shall not conduct activities with potential commercial applications that preclude or deter commercial space activities...." Further, it is the stated policy of the United States to "...encourage the development of commercial systems which image the Earth from space competitive with or superior to foreign operated civil or commercial systems." The commercialization of remote sensing may require implementation of U.S. Government policy options (Section F). The collective importance of these policy options underscores the need for a strong advocate within the U.S. Government to provide a central point of contact for ACERSS funding decisions, policy formulation, and management oversight.

Recommendations for consideration by the U.S. Government are presented in Section G. The recommended sensor suite calls for a 5m resolution stereoscopic Multispectral Linear Array supplemented by Enhanced Thematic Mapper and SeaWIFS instruments similar to those scheduled for Landsat 6. Ownership of the space segment should reside with an international consortium. The U.S. Government share in the consortium should be a controlling 40%. The required U.S. investment will be reduced, yet continued availability of data for U.S. users can be expected. A commercial entity should manage the U.S. share.

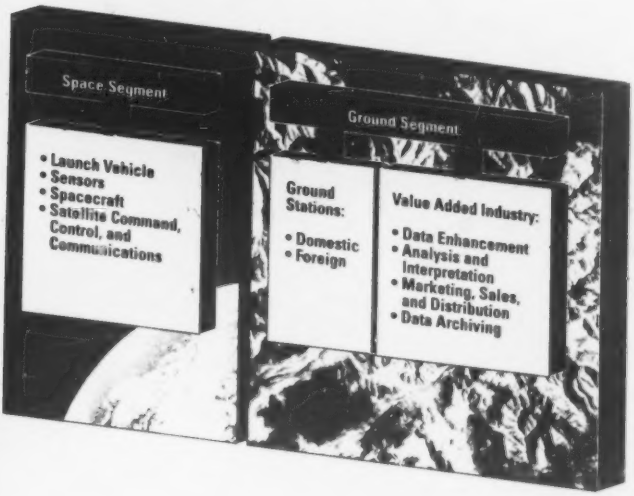


Figure 1. Space and Ground Segments of an Advanced Civil Earth Remote Sensing System (ACERSS). The owner/operator of the space segment bears all costs of domestic ground stations and collects access fees from foreign ground stations.

Future demand for ACERSS data and data products is projected in three market growth scenarios. Neither the 10 *ACERSS space segment nor the combined system (space plus ground segments) can be commercialized during the 1990s, even in the high growth scenario. By contrast, the value added industry—ground segment less ground stations—enjoys bright commercial prospects.*

B. CONCLUSIONS

The primary conclusions of this study concern the possibilities of commercializing an Advanced Civil Earth Remote Sensing System. Secondary conclusions concern the U.S. need for remote sensing data and the significance of continued United States participation in civil remote sensing beyond Landsat 6.

Projected Market Demand

The primary conclusions are based upon the range of total worldwide market demand projected for raw remote sensing data and value added information products. The range was determined primarily by applying three assumed market growth scenarios:

- Low growth (5%/year)—continuation of present market (zero real growth, as a background inflation rate of 5%/year for both costs and revenues is assumed throughout this study);
- Medium growth (12%/year)—stimulation of present market, but without introduction of new sensor technology;
- High growth (about 20%/year)—stimulation of present market, together with the introduction of new sensor technology in the 1990s in response to market demand.

These rates of market growth are consistent with projections developed earlier by KRS Remote Sensing through its own market studies. They are also consistent with the experience of other new, high technology industries.

Table 1 (page 12) summarizes market projections for the late 1990s in each scenario. Appendix 1 provides projections for individual segments of the market. In the high growth scenario, growth rates in some of these segments will vary from the norm as new technology meeting specific market needs is intoduced. All projections proceed from the same 1988 estimated base year revenues.

Table 1 shows that the total revenue available to value added vendors in the year 2000 will range from approximately $100 to $375 million; revenues available to space segment operators will be considerably lower in each scenario. With multiple operators competing for a share of this market, each space segment operator would realize significantly less than $200 million annually even in the high growth scenario.

Commercialization Potential

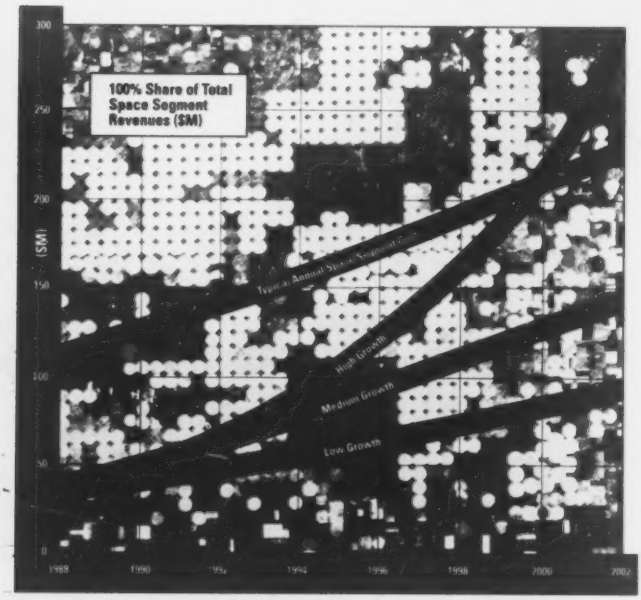
Figure 2 compares these space segment revenue projections with representative annualized costs of successive Landsat-type space segments involving launch of a single satellite every 3 years. These costs range from $120 to $220 million/year during the 1990s, based on a combined sensor, satellite, and launch cost of $285 million in 1988 dollars (neglecting insurance costs) and a 3 year mission lifetime. These costs would have to be greatly (and implausibly) lower to alter the following primary conclusions:

(1) The space segment cannot be commercialized during the present century, even under the most optimistic market projections. Even in the high growth scenario and assuming an unrealistically high 100% share of the total world market for raw data and foreign

ground station fees, a Landsat-type system involving succesive, single satellites would not cover its space segment costs until about the year 2000. Such revenues would still fail to provide a commercially competitive return on investment, and thus would not interest private investors.

(2) The ground segment (exclusive of ground stations), considered independently, can undergo complete and profitable commercialization during the 1990s. Figure 3 (page 13) compares projected total value added product sales with projected total space segment revenues during the 1990s in the medium growth and high growth scenarios. In both scenarios, revenues to the ground segment surpass revenues to the space segment. Costs of the ground segment are considerably lower, yielding significant entrepreneurial opportunities by the time of ACERSS or earlier. Much of the increase in value added purchases is projected to come from private industry; as processing technologies mature, image information products will be used as major decision-making tools. Much of the projected increase in raw data sales is attributed to large users (such as DoD) processing data for their own use; the additional ground segment market for related computer systems is neglected in the tabulations.

11



Typical annual cost of Landsat-type space segment, assuming 3 year mission lifetime and 5%/year inflation

Low, Medium, High Growth: Projected total space segment revenues

Figure 2. Space Segment Revenue Shortfall: typical annual space segment cost compared with projected total annual revenues from raw data sales and foreign ground station fees in three market growth scenarios. Projected space segment revenues cannot cover space segment costs during the 1990s, even assuming a 100% market share of such revenues in the high growth scenario.

(3) The combined system—space plus ground segments—cannot be commercialized during the present century. Given a 50% share of the total world market, revenues to the ground segment could not cover the deficits of the space segment until 1997, let alone provide a competitive return to private space segment investors.

The curve in Figure 4 (page 14) showing space segment costs is the same as that in Figure 2. By contrast with Figure 2, however, the revenue curves represent a realistic 50% share of the combined world market revenues from both the space segment *and* the value added industry. Even in the high growth scenario, revenues to the combined system fall below space segment costs until 1997. The disparity increases if the costs of insurance and value added product development are included. Thus, even a 50% market share of projected total high growth revenues will not cover costs of the combined (space plus ground segments) system.

12

(4) United States Government investment in the space segment is necessary for U.S. participation in an Advanced Civil Earth Remote Sensing System.

Conclusions (1) through (3) lead directly to conclusion (4). The space segment alone cannot be fully commercialized in this century.

Table 1. Projected Total Revenues from raw data sales, foreign ground station fees, and value added products during the late 1990s in three market growth scenarios. By the year 2000, in the high growth scenario, total annual revenue is approximately $0.6 billion.

Low Growth (SM)	*1988*	*1996*	*1997*	*1998*	*1999*	*2000*
Raw Data Sales	27.2	44.0	46.3	48.8	51.0	53.5
Ground Station Fees	12.0	21.6	22.8	24.0	25.2	26.4
SPACE SEGMENT REVENUE	**39.2**	**65.6**	**69.1**	**72.8**	**76.2**	**79.9**
Value Added Products	51.8	82.8	86.8	90.9	95.3	99.9
TOTAL REVENUE	**91.0**	**148.4**	**155.9**	**163.5**	**171.5**	**179.8**
Medium Growth (SM)						
Raw Data Sales	27.2	69.4	77.3	86.3	96.3	107.5
Ground Station Fees	12.0	21.6	22.8	24.0	25.2	26.4
SPACE SEGMENT REVENUE	**39.2**	**91.0**	**100.1**	**110.3**	**121.5**	**133.9**
Value Added Products	51.8	120.9	133.3	146.8	161.9	178.7
TOTAL REVENUE	**91.0**	**211.9**	**233.4**	**257.1**	**283.4**	**312.6**
High Growth (SM)						
Raw Data Sales	27.2	105.7	124.1	144.9	168.9	196.7
Ground Station Fees	12.0	21.6	22.8	24.0	25.2	26.4
SPACE SEGMENT REVENUE	**39.2**	**127.3**	**146.9**	**168.9**	**194.1**	**223.1**
Value Added Products	51.8	190.4	227.0	268.4	317.3	374.0
TOTAL REVENUE	**91.0**	**317.7**	**373.9**	**437.3**	**511.4**	**597.1**

Figure 3. Growth of Value Added Market: projected valued added sales compared with projected space segment revenues during the late 1990s. Value added sales surpass space segment revenues in both medium and high growth scenarios.

Case For Continued United States Participation

Given this fundamental reasoning, secondary conclusions have been drawn concerning noncommercial judgements that warrant continued United States participation in civil remote sensing:

(5) The United States has important national needs for civil Earth remote sensing data to support U.S. interests, both internally and abroad.

Examples of needs falling into the category of a "public good" include use of a remote sensing system for:

- *Conduct of United States foreign policy.* The U.S. Agency for International Development and the USDA Foreign Agricultural Service, for example, both rely heavily on civil Earth remote sensing data for development assistance and key policy decisions.

- *Promotion of U.S. economic growth.* Remote sensing is utilized extensively by private industry in the competitive, worldwide search for natural resources. If there is no United States participation in ACERSS, it is questionable whether foreign sources of data would grant U.S. firms the unrestricted access required for open competition, thus jeopardizing U.S. economic interests.

Typical annual cost of Landsat-type space segment, assuming 3 year mission lifetime and 3%/year inflation

Low, Medium, High Growth: Projected total revenues from raw data sales, ground station fees and value added data products

Figure 4. Combined System Revenue Shortfall. Typical annual space segment cost compared with 50% market share of projected total revenues from all sources in three market growth scenarios. Even in the high growth scenario, commercialization of the combined system (space plus ground segments) is infeasible.

• *Provision of research data* for study of changes in the global environment. Continuous, long-term space-derived data sets are essential for scientific research. While future research missions will provide much of the needed data, an ACERSS will provide a timely extension of present data sets and contribute important new information.

• *Demonstration of U.S. technological leadership* and elevation of national prestige. Developing countries, in particular, look to the most technologically advanced nations for assistance in planning their own economic growth. This planning often requires information best derived through satellite remote sensing.

• *Enhancement of national security.* The Department of Defense is currently the largest Federal purchaser of raw data from civil remote sensing systems, primarily to meet the needs of the Defense Intelligence Agency and the Defense Mapping Agency. DoD has instituted an extensive image interpretation training program to expand capabilities for in-house data analysis and evaluation. 15

• *Enforcement of national laws and policies,* such as those governing environmental pollution, legal disputes, and illegal substances.

An advanced U.S. system would continue and expand a national commitment to technological excellence. Abdication of technological leadership at this point would only underscore the rapid strides being made by Europe, Japan, and the Soviet Union. Continued United States participation in civil Earth remote sensing may also be necessary to assure continuation of the present, international "Open Skies" policy of nondiscriminatory data availability. This policy is widely believed to bring important economic and political benefits to many nations around the world.

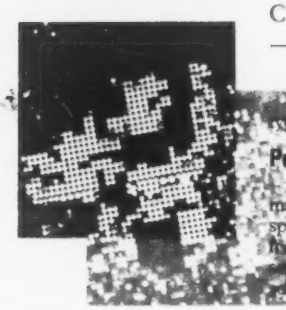
(6) Sources of data and information needed by the United States but that originate outside the United States cannot be deemed reliable under all circumstances.

Data from remote sensing systems now planned by the National Aeronautics and Space Administration (NASA) for the future may not meet the needs of the commercial marketplace. For example, the Earth Observing System (Eos) is being designed as a research system, rather than a commercial one. Therefore, a decision to forfeit commercial leadership in this field pioneered by the United States means heavy reliance on foreign sources to meet U.S. civil needs. This in turn brings somewhat higher risk of interruption of the data flow to U.S. Government agencies and U.S. industry, even though political and economic ties with likely foreign sources are currently strong.

Taken together, conclusions (5) and (6) lead to the following:

(7) To ensure reliable access to nationally needed data and information, the United States must either maintain its own Advanced Civil Earth Remote Sensing System or hold a controlling interest in an international system.

C. TECHNICAL OPTIONS



Sensor types are evaluated according to their ability to contribute to data products in high commercial demand. Five sensor types will meet 16 *most needs of the civilian and DoD markets in the 1990s.*

The market driven technology assessment has identified five sensor types as meeting the preponderance of civilian and DoD market needs.

Performance Requirements

Table 2 summarizes the requirements of the most important domestic market segments during the late 1990s with respect to spatial capabilities, spectral regions, and revisit interval. The requirements of the substantial foreign markets are judged to be similar. As the table shows, all of these segments require some ultrahigh resolution imagery in the high growth scenario.

Figure 5 compares market demands for high spatial resolution and rapid information delivery (fast turnaround time) to the performance levels currently available from civil systems. Landsat 5 provides only 30m spatial resolution and offers relatively slow turnaround times to the civilian market. The French SPOT system, although more restricted than Landsat 5 in terms of spectral resolution and geographic coverage per scene, surpasses it in both spatial resolution and turnaround time. Nevertheless, demand for 5m or better spatial resolution *and* fast turnaround times is not currently being met by civil systems.

Sensor Options

A data base containing technical summaries of 162 sensor types with the potential to provide the required performance was reviewed. About half of these sensors were deemed suitable for use in an Advanced Civil Earth Remote Sensing System and classified into the following generic types:

- Altimeter (ALT)
- High frequency microwave radiometer (HFMR)
- High resolution visible/infrared radiometer (HRV/IR)
- Infrared sounder (IRS)
- Low frequency microwave radiometer (LFMR)

Table 2. Market Driven Technology Requirements for the period 1995-2000, ranked in order of market size projected by the high market growth scenario. All market segments have some demand for higher spatial resolution and more frequent revisit than provided by current civil systems.

Markets		*Spatial*			*Spectral*					
					VISIBLE/INFRARED			MICROWAVE		
Market	Market Rank	Resolution (m)	Absolute Location a.y.e (m)	Swath (km)	V/NIR	SWIR	TIR	Active	Passive	Revisit (days)
U.S. Government (Non-DoD)	1	5-10k	5	60-1000	•	•	•	•	•	1-365+
Extraction	2	5-1k	10	60-1000	•	•	•	•	•	1-365+
Agribusiness	3	5-10k	10	60-1000	•	•	•	•	•	1-365+
Simulation	4	5-30k	10	60-200	•	•	•	•		90-365+
Legal	5	5-30k	10	60-200	•	•	•	•		1-365+
Utilities	6	5-10k	5	60-200	•	•	•	•		1-365+
DoD	7	3-40k	5	15-200	•	•	•			1-365+
Media	8	5-1k	10	60-1000	•	•	•	•		1-365+
Mapping	9	3-10k	5	60-200	•			•		365+
State & Local Government	10	5-10k	5	60-1000	•	•	•	•	•	1-365+

- Moderate resolution visible/infrared radiometer (MRV/IR)
- Microwave sounder (MS)
- Real aperture radar (RAR)
- Scatterometer (SCATT)
- Synthetic aperture radar (SAR)
- Ultrahigh resolution visible/infrared radiometer (URV/IR)

Table 3 (page 18) summarizes the characteristics and typical applications of these sensor types and provides representative examples.

Market Driven Sensor Assessment

Figure 6 (page 19) illustrates the process by which these sensor types were evaluated to determine the ones that could operate as the most commercially viable sensor suites. The market segments were analyzed to identify their application needs, then the applications were weighted according to projected market revenue. Next, products that met the

17

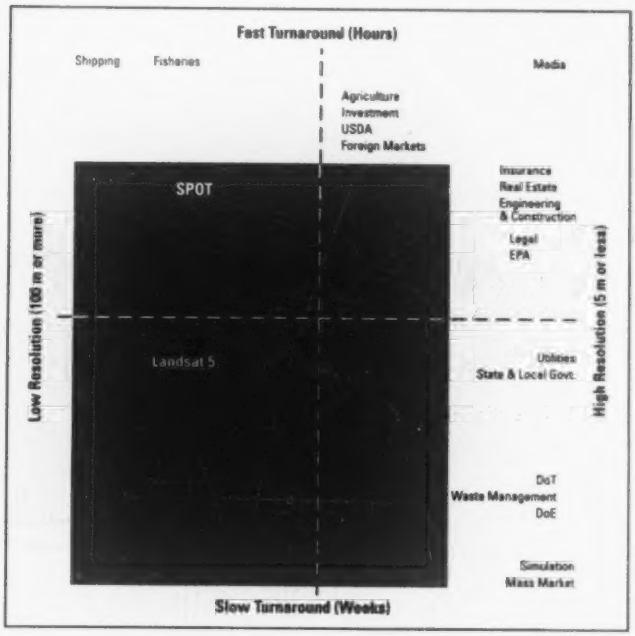


Figure 5. Qualitative Assessment of Current Technology compared with some market segment needs. The current SPOT and Landsat sytems cannot supply the high spatial resolution and rapid turnaround time demanded by many potential new market segments.

applications needs were identified and weighted. Finally, sensor types able to provide the most heavily weighted product needs were identified. Appendix 2 describes the weighting process in more detail. The results showed that the five sensor types in greatest demand by the civilian market are:

- A sensor with ultrahigh spatial resolution (5m or better) for the visible and near infrared spectral regions, preferably with along track stereoscopic capability for accurate topographic mapping. Example: a 5m stereo Multispectral Linear Array (MLA).

- A sensor with high spatial resolution (30m) in visible and infrared spectral bands of proven utility. Example: the Enhanced Thematic Mapper (ETM) scheduled to be flown aboard Landsat 6, which provides panchromatic 15m resolution in addition to continuity with earlier Thematic Mapper (TM) capabilities.

18

- A synthetic aperture radar (SAR) for all weather, day and night coverage at high spatial resolution (10-20m). Example: the SAR planned for the Canadian RADARSAT mission.

- A moderate resolution (1 km) radiometer providing broad swath images in the visible and near infrared spectral regions. Examples: the Sea Wide Field Sensor (SeaWIFS) to be carried aboard Landsat 6, or the Advanced Very High Resolution Radiometer (AVHRR) aboard present NOAA polar orbiting environmental satellites.

- A low frequency microwave radiometer, for a variety of temperature and other measurements. Examples: passive microwave radiometers aboard present or future NOAA polar orbiting satellites.

The sensors that satisfy the DoD information needs are very similar to those that will satisfy the non-DoD market. If sensors addressing DoD

Table 3. Sensor Types evaluated in the present study. Representative examples of these sensor types are already in use or planned for a variety of remote sensing missions.

Sensor Types	*Instrument Class*	*Frequency, Spectral Range*	*Resolution*	*Swath Width*	*Representative Sensors*
ALT	Radar	13.5 GHz	10 cm (vertical) 1.8-8.1 km (horizontal)	Nadir only	Geosat Alt
SCATT	Radar	15.0 GHz	25 km	600 km each side	NASA SCATT
SAR	Synthetic Aperture Radar	L thru X Band	10-20 m	25-200 km	ERS-1, JERS-1
RAR	Real Aperture Radar	X Band	0.5-1.5 km	500-700 km	COSMOS 1766
LFMR	Microwave Radiometer	5-35 GHz	10-25 km	1400 km	ESTAR, AMSR (Eos)
HFMR	Microwave Radiometer	35-85 GHz	1-15 km	1400 km	AMSR (NOAA)
MS	Microwave Sounder	23-190 GHz 15-30 channels	40 km	2200 km	AMSU A, AMSU B
IRS	IR Sounder	0.2-15 μm 20 channels	20 km	2200 km	HIRS/3
HRV/IR	V/IR Radiometer	0.4-14 μm up to 200 channels	less than 100 m	40-200 km	HIRS, ETM
MRV/IR	V/IR Radiometer	0.4-14 μm up to 100 channels	500-1000 m	1000-2700 km	MRIR; MODIS
URV/IR	V/IR Radiometer	0.4-14 μm	5 m	80 km	MLA

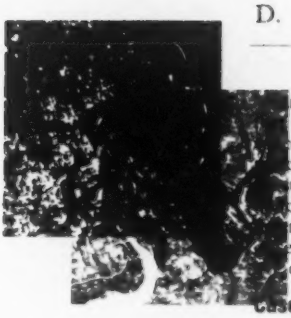
needs are flown on an ACERSS, they will satisfy all needs of the non-DoD markets, assuming that civilian SAR and SeaWIFS-like data are also available. Among these five types, the MLA and the SAR would require the most development effort to enable launch of a commercially useful system by the mid-1990s.

Given current planning (see Section D), the SAR sensor on ERS-1 will be followed by SARs launched on JERS-1 (1992), RADARSAT (1994), and on the European Eos Polar Platform (1997) and the NASA Eos Polar Platform (1998). Current plans call for at least one orbiting SAR sensor available to provide data to Earth resource users until the turn of the century. The high cost and long lead time required for development of an operational satellite SAR also argue against a U.S. effort that extensively duplicates other planned capabilities. On the other hand, the United States can establish pre-eminence by developing and flying an advanced sensor (such as a stereoscopic MLA) that will provide some unique capabilities while still satisfying a large number of market requirements.

Multispectral imagers with various spatial resolutions have a long history of use in remote sensing. Consequently, user familiarity with the utility of data from an MLA would be relatively high. A SAR system, by contrast, is not likely to gain immediate commercial acceptance. Civilian use of SAR imagery until now has been largely confined to exploratory research. SAR imagery is not expected to be in high commercial demand during the 1990s even in the high growth scenario. It was therefore accorded lower priority when configuring viable sensor suites (see Section D).

Figure 6. Schematic Illustration of Market Driven Technology Assessment used to rank sensor types on the basis of contribution to data products in high commercial demand. Five sensor types stood out as those in highest demand by the civil market.

D. IMPLEMENTATION OPTIONS



n advanced system should have one or more of the five sensor types were shown in Section C to be the most commercially viable. The e segment share of world market revenues will vary, depending on combination of sensors chosen and on the type of ownership option ued. These same factors will also strongly affect costs, and thus are chief determinants of a system's revenue-to-investment ratio. To rmine the optimum United States investment strategy, a broad range nsor/ownership implementation options was analyzed and quantita- comparisons made.

ase for International Ownership

A striking change has occurred in the satellite remote sensing industry since passage of the Land Remote Sensing Commercialization Act of 1984 (P.L. 98-365). The industry has become internationally competitive. The French SPOT system, in operation since 1986, is now providing significant competition to the current Landsat systems, which are managed by the Earth Observation Satellite Company (EOSAT). Sales by SPOT to U. S. Government agencies and private industry in 1988 are estimated to equal 80% of EOSAT's U.S. sales. The French plan a series of SPOT missions offering successive advances in sensor technology.

Combinations of the five preferred sensors are paired with choices of U.S. ownership share to yield ten implementation options for the ACERSS space segment. U.S. revenues projected by an appropriate market growth scenario are then compared with required U.S. investment for each of the options.

20

Systems are also planned by the European Space Agency (ERS-1), Japan (JERS-1), and other entities. Some of these groups are expected to make data commercially available to the world marketplace. Figure 7 summarizes the international remote sensing missions scheduled for the 1990s. Six countries (excluding the U.S. and ESA) have plans for their own space segment. Increasingly, alternatives to data supplied by the United States will become available, and recommendations for system ownership must take this fact into account.

The principal ownership options studied are 100% U.S. ownership, a U.S. share in an international consortium, and bilateral ownership. These are compared in Table 4 (page 22), which shows international ownership to be more advantageous than 100% U.S. ownership—if the U.S. share is large enough to ensure a controlling U.S. influence on policies. A bilateral partnership would be the simplest form of international agreement to negotiate. Two key issues highlighted in the table are addressed below.

The Department of Defense would prefer 100% United States ownership of an Advanced Civil Earth Remote Sensing System. However, DoD should view a controlling 40% ownership share in an international consortium as acceptable, since DoD will not allow the existence or availability of civil Earth remote sensing data to become critical to U.S. security. An arrangement that ensures U.S. control of the assets of a remote sensing system would adequately protect the nation from the risk of data interruption. Such an arrangement is an acceptable alternative to complete reliance upon foreign sources and would be sufficient for continued DoD use of civilian remote sensing data.

An international consortium may be difficult to negotiate, particularly in time for ACERSS launch in 1995 . Hence it will be important to select partners that are already bound to the United States by international

treaties or who are parties to other space-related U.S. negotiations. Partners in the former class include members of the International Telecommunications Satellite Organization (INTELSAT), the International Maritime Satellite Organization (INMARSAT), and the North Atlantic Treaty Organization (NATO). Those in the latter class include international participants in the Space Station program and the Earth Observing System (Eos).

A bilateral ownership arrangement would be simpler to negotiate. For example, the vast northerly nation of Canada would be well served by extensive remote sensing from polar orbit. Plans for a Canadian synthetic aperture radar mission (RADARSAT), intended primarily for Canadian ice and snow studies, are already well advanced. Funding difficulties, however, have delayed RADARSAT development. Although no bilateral discussions have been held to explore this possibility, the study team believes that Canada could be receptive to inquiries about collaboration with the United States.

Viable Options

To illustrate the broad range of viable implementation options for an advanced system, ten combinations of sensor suite/ownership structure

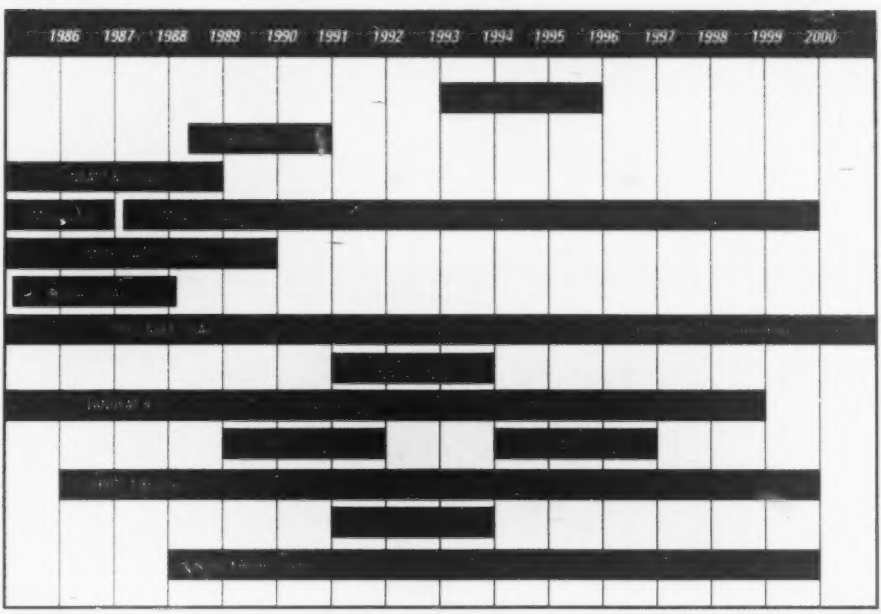


Figure 7. International Remote Sensing Missions through the year 2000. Developing countries, as well as industrialized nations, will be participating in satellite remote sensing programs during the next decade.

were analyzed. The first three options involve no new sensor technology and have been included to provide a baseline for comparison with advanced options:

(1) SeaWIFS/USA—a single SeaWIFS sensor aboard a small satellite ("Lightsat"), with 100% U.S ownership.

(2) LS-6/USA—reflight of the Landsat 6 sensors (ETM, SeaWIFS), with 100% U.S. ownership.

(3) LS-6/Intl—reflight of the Landsat 6 sensors, but assuming a controlling 40% U.S. ownership share in an international consortium.

Six additional options involve more advanced instruments:

(4) 3 ADV/USA—three advanced sensors—5m stereo MLA, ETM, and SeaWIFS—with 100% U.S. ownership.

22

(5) 3 ADV/Intl—the three advanced sensors of Option 4, but assuming a controlling 40% U.S. ownership share in an international consortium.

Table 4. Case For International Ownership of the space segment. International partnerships lower U.S. investment and increase the likelihood of greater market share.

Ownership Option	Advantages	Disadvantages
100% United States Ownership	• Best guarantee of data continuity to U.S. users • Best means for assuring "Open Skies" and "Non-discriminatory access" • Maximum flexibility and control in setting system specifications • Demonstration of continued U.S. leadership	• Highest U.S. investment • Possible loss of revenue because of reduced market share
Bilateral Ownership	• Lower U.S. investment • Likelihood of greater market share for the space segment * • Talent pooling • Conservation of capital	• Time consuming negotiations required
International Consortium	• Lowest U.S. investment • Likelihood of greatest market share for the space segment * • Maximum talent pooling • Maximum conservation of capital	• More difficult and lengthy negotiations required • Risk of interruption of data to U.S. users if U.S. does not have a controlling share • Difficulty in establishing government/industry partnership for managing the U.S. share

* Market share and revenue increase if the cooperating nations would otherwise have been competitors

(6) SAR/Bilat—a SAR flown as part of a bilateral agreement, assuming a 50% U.S. ownership share.

(7) SAR/Intl—a SAR, assuming a controlling 40% U.S. ownership share in an international consortium.

(8) 3 ADV + SAR/Bilat—a 5m stereo MLA, ETM, SeaWIFS, and SAR, flown as part of a bilateral agreement, assuming a 50% U.S. ownership share. Note that, in terms of the sensors flown, this option is simply the combination of Option 5 with Option 6; the SAR would be flown on a separate satellite.

(9) 3 ADV + SAR/Intl—the sensors of Option 8, but assuming a controlling 40% U.S. ownership share in an international consortium. See also the note above (Option 8).

A tenth option involves use of two of the polar platforms planned as part of the proposed international Earth Observing System (Eos); five commercial instruments would replace several proposed research instruments:

(10) 4 ADV + SAR/Intl—a 5m stereo MLA, ETM, SeaWIFS, passive microwave radiometer, and SAR, assuming a controlling 40% U.S. ownership share in the international Eos consortium.

Table 5 presents estimated costs and projected revenues for these options. The U.S. investment (column C) is the space segment cost multiplied by U.S. ownership share. Active market stimulation is assumed for all options, leading to medium or high market growth; however, only those options featuring advanced, high resolution multispectral sensors are

23

Table 5. Financial Summary of Ten Space Segment Implementation Options characterized by choice of sensor suite and assumed U.S. ownership share. The ratio of U.S. space segment revenues to U.S. space segment investment is a measure of the benefit of the option to the United States.

Space Segment Implementation Option	U.S. Ownership Share	Space Segment Cost ($M 1995)	U.S. Investment ($M 1995)	Assumed Market Growth Scenario	Total Space Segment Revenues, 1996-98 ($M)	Assumed Market Share	Revenues to System, 1996-98 ($M)	Revenues to U.S., 1996-98 ($M)	Ratio, U.S. Revenues to U.S. Investment
1) SeaWIFS/USA	100%	108	108	MEDIUM	301.4	5%	15.1	15.1	0.14
2) LS-6/USA	100%	310	310	MEDIUM	301.4	30%	90.4	90.4	0.29
3) LS-6/INTL	40%	310	124	MEDIUM	301.4	40%	120.6	48.2	0.39
4) 3 ADV/USA	100%	402	402	HIGH	443.1	40%	177.2	177.2	0.44
5) 3 ADV/INTL	40%	402	161	HIGH	443.1	50%	221.6	88.6	0.55
6) SAR/BILAT	50%	402	201	MEDIUM	301.4	9%	27.1	13.6	0.07
7) SAR/INTL	40%	402	161	MEDIUM	301.4	15%	45.2	18.1	0.11
8) 3 ADV + SAR/BILAT	50%	804	402	HIGH	443.1	50%	221.6	110.8	0.28
9) 3 ADV + SAR/INTL	40%	804	322	HIGH	443.1	65%	288.0	115.2	0.36
10) 4 ADV + SAR/INTL (2 SS Polar Platforms)	40%	1290	518	HIGH	443.1	70%	310.2	124.1	0.24

paired with the high growth scenario. Total space segment revenues (column E) from raw data sales and ground station fees for the years 1996 through 1998 are those projected from Table 1 to be available for all competing space segments worldwide over the 3 year mission lifetime of ACERSS. Multiplication by the assumed market share yields revenues to the system (column G); multiplication of system revenues by U.S. ownership share yields revenues to the United States (column H). Revenue to the United States is less than U.S. investment in every case, illustrating once again the lack of commercial possibilities for the space segment. Nevertheless, the greater the ratio of revenue to investment (column J), the more beneficial the option to the United States.

The Implementation Options Compared

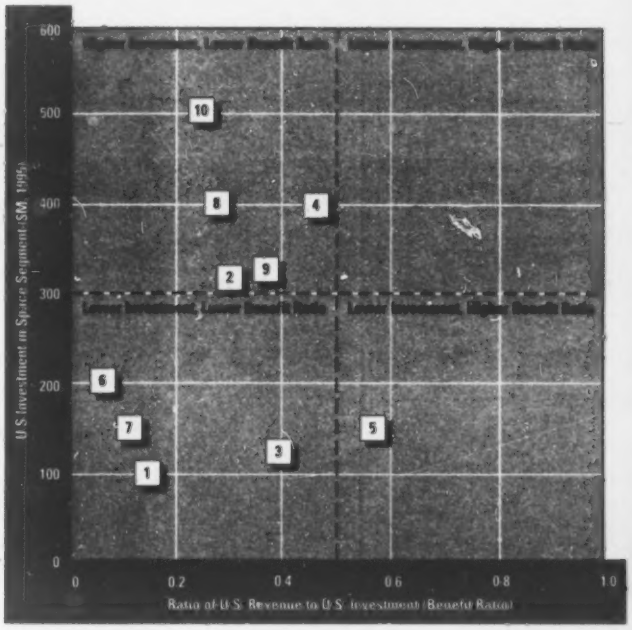
Figure 8 arrays the ten options according to the U.S. investment required and the resulting U.S. revenue/investment ratio. Option 5 is the most beneficial to the nation (under the assumptions of Table 5) and also requires relatively low U.S. investment. This option consists of three advanced sensors—a 5m stereo Multispectral Linear Array, an Enhanced Thematic Mapper, and a SeaWIFS or equivalent—with the U.S. Govern-

24

Figure 8. Comparison of Space Segment Implementation Options on the basis of U.S. investment and the revenue/investment ratio (the benefit ratio). Lower investment and higher benefit ratio distinguish Option 5: flight of three advanced multispectral sensors, with a controlling 40% U.S. ownership share in an international space segment consortium.

KEY:

(1) Sea WIF/USA
(2) LS-6/USA
(3) LS-6/INTL
(4) 3 ADV/USA
(5) 3 ADV/INTL
(6) SAR/BILAT
(7) SAR/INTL
(8) 3 ADV + SAR/BILAT
(9) 3 ADV + SAR/INTL
(10) 4 ADV + SAR/INTL
(2 SS Polar Platforms)



ment holding a controlling 40% ownership share in an international consortium. The nearest competitors to Option 5, in terms of U.S. revenue/investment ratio, are options 3 and 4.

Option 3 provides for reflight of the Landsat 6 sensor suite (ETM and SeaWIFS) with international space segment ownership; it thus differs from Option 5 only through the omission of a 5m stereo MLA. Required U.S. investment is correspondingly lower. Because it omits the advanced MLA capability, however, Option 3 is assumed to gain only a 40% market share of medium growth revenues. The benefit ratio for Option 3 is therefore substantially less than that for Option 5. As a result, the net cost (U.S. investment less U.S. revenues) is slightly greater for Option 3 ($75.8 million) than for Option 5 ($72.4 million).

Option 4 involves the same advanced sensor suite as Option 5 but specifies 100% U.S. ownership. The required U.S. investment is thus the full cost of the space segment. Moreover, it is assumed that a completely domestic system would gain only a 40% market share of high growth revenues, in contrast to an assumed 50% share for the international system. The financial benefit ratio for Option 4 is thus smaller than that for Option 5. On a non-financial basis, however, Option 4 has the advantages of 100% U.S. ownership (see Table 4).

A more comprehensive measure used to gauge commercial viability is the net present value (NPV) of the associated financial transaction. The NPV of the identified options is summarized in Appendix 3, which further details the very low prospects for commercializing the space segment.

Development and Negotiation Schedule

Development of an advanced system will typically require 6 to 10 years from program commitment to launch. Four to five years will be needed for sensor development, on the assumption that advanced sensors, such as a 5m stereo MLA, will be specified. If this is the case, a 1995 launch of ACERSS is possible only if long-lead actions, such as planning, responsibility assignment, and contractor selection begin in calendar year 1990 or earlier.

If international ownership is specified, negotiations aimed at launch of an advanced system by 1995 would almost certainly have to begin early in calendar year 1989. Even then, success would be likely only if the negotiating partners have a previously established structure within which to work (e.g., INTELSAT, INMARSAT, NATO) or are already participants in continuing space-related negotiations (e.g., Space Station, Eos).

25

E. MANAGEMENT OPTIONS

The ACERSS space segment should be privately managed. At present, the United States has no real model of the government-industry partnership that may be needed to promote more extensive ACERSS commercial participation.

s Section D has shown, an Advanced Civil Earth Remote Sensing em is not, in totality, a commercial possibility for the 1990s: although ground segment can be commercialized completely (except for the nd stations), the space segment cannot. There are, however, oppor- ies for United States industry participation in the space segment ough private sector management and a possible Government-industry nership.

Private Sector Management

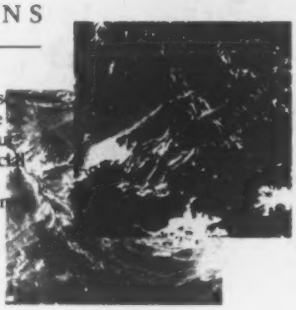
he present experiment for private sector management of the Landsat space segment should continue through a competitive selection process for ACERSS management services. It is highly desirable to have a private sector manager of the space segment (or of a U.S. share) in order to present an effective working interface to the value added industry.

Government-Industry Partnership

The United States is perhaps unique in the industrialized world in its enforcement of the separation between government and industry. As a result, the U.S. has no real model of the government-industry partnership that may promote commercial participation in the ACERSS program.

This type of arrangement would provide access to the full range of corporate finance instruments, such as bond issues, for supplementary or alternative financing. While substantial Government investment could not be avoided, this approach offers a method to spread the Government investment share over several years.

F. POLICY OPTIONS



Policy options for the United States Government fall into three class restructuring of system costs, reduction of business costs, and increase revenues to the system. Most of these have been suggested before, bu they now assume renewed importance in view of the lack of commerci possibilities for the space segment. The length and variety of the list underscore the importance of establishing a single U.S. Government en for ACERSS funding decisions, policy formulation, and management oversight.

Policy options include restructuring of system costs, reduction of business costs, and increase of revenues. The collective importance of these options underscores the need for a strong ACERSS advocate within the U.S. Government to provide a single point of contact for ACERSS funding decisions, policy formulation, and management oversight.

Restructuring of System Costs

The following are viable options open to the U.S. Government:

(1) Sharing of the satellite bus production line presently used for the spacecraft of the Defense Meteorological Satellite Program (DMSP) or the NOAA polar orbiting satellite program.

Use of a standard satellite bus for future ACERSS missions would presumably lower spacecraft R&D costs and bring economies of scale into the program. This approach is already being followed by NOAA and DoD in the production of spacecraft for their respective series of meteorological satellites.

(2) Provision of capabilities on polar orbiting satellites with morning Equatorial crossing times, such as the morning NOAA satellites or the European Eos polar platform.

For many applications, morning satellite overpass is preferable to afternoon because of the probability of lower cloud cover. It is not clear that sufficient provision could be made for an advanced instrument suite on NOAA spacecraft as presently planned, but perhaps a single additional instrument could be accommodated without extensive redesign. A more ambitious approach would consider a more capable NOAA spacecraft expressly designed to accommodate selected ACERSS instruments in the future. The proposed Eos satellites present a similar opportunity, but it is the European platform that is scheduled for a morning crossing time, so that international negotiation would be required.

(3) Provision of launch without charge to the program.

Typical costs for launch by a U.S. rocket of the required capability lie in the range $50-60 million, so this option would represent a substantial savings to the program. The main attraction of this option is that it would provide a politically more acceptable means of support than a funding subsidy.

(4) Sharing of multiple launch service procurements, such as DoD procurements of the Titan II rocket.

The Department of Defense is now procuring substantial numbers of rocket launches for DoD payloads. Since DoD displays a growing interest in the use of civil Earth remote sensing data and has a preference for U.S. data sources, some accommodation of the ACERSS program might be arranged that would reduce the launch cost to the program. The U.S. Government may prefer this arrangement to use of low cost foreign launches, such as those now being offered by the Chinese on their "Long March" rocket.

(5) Funding the development of new system elements, particularly sensors.

As in the case of launch provision, this option may be politically preferable to an outright subsidy. Moreover, such development could take place through existing funding channels for sensor R&D, for example, at NASA's Goddard Space Flight Center and at the Jet Propulsion Laboratory, both of which have traditionally been active in the development of sensors for NASA missions. Funding for development through university laboratories could be included here as well.

28

(6) Provision of ACERSS funding through direct Congressional appropriations for the International Space Year (ISY) in 1992.

Although Congress has passed legislation declaring ISY, no significant funding has yet been provided. However, an Earth science initiative is among the scientific components of the proposed ISY program and is under study by the U.S. National Academy of Sciences. A portion of future funding appropriated by the Congress could be earmarked for an ACERSS advanced sensor suite that would continue a data stream already in active research use.

(7) Funding of certain ACERSS needs jointly with other, related U.S. programs.

The Government is already supporting, or planning to support, activities that have a direct bearing on the needs of ACERSS. For example, the proposed Earth Observing System now under study by NASA will require a highly capable information system. A portion of the Eos data system might be developed in advance and utilized by ACERSS, with funding provided by NASA; the data system would revert to Eos following ACERSS completion. In addition, NASA is sponsoring remote sensing investigations at two of its Centers for the Commercial Development of Space (CCDS) through its Office of Commercial Programs (OCP) and through a newly established joint program sponsored by NASA's Office of Space Science and Applications and OCP. NASA funding for these activities might be correlated with ACERSS needs and provide partial support.

Reduction of Business Costs

The U.S. Government may supplement the system options above with other steps designed to reduce business costs to private sector firms involved in ACERSS. Examples are:

(1) Provision of tax incentives for investment.

Private investment in the space segment might be encouraged by favorable tax treatment, similar to the R&D investment tax credit designed to encourage corporate investment in research.

(2) Underwriting of insurance for third-party liability, loss of spacecraft, loss of revenue, or other perils.

Government launches and other space activities are typically self-insured, but private investors will in general insist on insurance, at least for liability and loss of spacecraft. Government underwriting of these and other risks would increase the attractiveness of commercial investment.

29

(3) Limitation of liability insurance by law.

As an alternative to underwriting, the Government could limit the liability any commercial party could incur and assume all additional risk. Limits to the insurance coverage that is now required of U.S. commercial launch operators is presently under discussion in the Congress.

(4) Provision of loans bearing little or no interest.

Such loans might enhance prospects for commercial investment in the space segment and would be politically preferable to outright subsidies.

(5) Provision of tax incentives for "gifts" to ACERSS.

Portions of ACERSS costs, such as data processing equipment, might be donated by industry under favorable tax conditions. The same could apply to the furnishing of site facilities by a private sector manager of the space segment.

(6) Funding of technique development.

Various techniques that contribute to the cost of development or operations (e.g., data processing techniques) might be funded through related Federal programs.

(7) Granting of highest possible priority access to the Tracking and Data Relay Satellite System (TDRSS).

Advanced sensors—particularly multispectral, high resolution imagers and synthetic aperture radars—place a heavy burden on communications capabilities. Highest possible priority access to the 300 megabit/second TDRSS system would remove a significant uncertainty in planning for commercial operations at high data rates.

Increase of Revenues

The U.S. Government may at the same time seek to increase revenues through additional steps. Examples are:

(1) Guarantees of substantial Federal agency data purchases.

The present prohibition of guaranteed Government purchases of satellite data should be abandoned. Federal agencies such as the U.S. Department of Commerce have a mission to support U.S. industry, and U.S. industry is projected to increase its use of civil Earth remote sensing data. It follows that agencies must make increasing use of such data themselves simply to be able to carry out their missions. The guarantees of data purchase could take the form of support for agency projects either planned or already required—for example, the mapping of the United States to a scale of 1:50,000 by the U.S. Geological Survey, or a detailed survey of arable land by the Department of Agriculture. However, such guarantees are apt to be viewed with skepticism unless they are strengthened by Congressional legislation and budget allocation.

30

(2) Allowance, by law, of discriminatory data pricing (e.g., the granting of exclusive data rights to the buyer under specified conditions).

The word "discriminatory" carries two connotations. In the language of standard microeconomics, "perfect price discrimination" refers to the pricing of commercial goods or services so as to obtain optimum revenue from each market segment. The market survey indicates, for example, brisk future demand for high spatial resolution and rapid data delivery. An aggressive pricing policy could increase revenues by "auctioning off" these valued characteristics to the highest bidder. Such a commercial policy of perfect price discrimination in the microeconomic sense would not conflict with present government "nondiscrimination" policies; data would be made available to anyone willing to pay the price.

In addition, the Government may wish to change its present policies so as to allow, under specified conditions, the sale of exclusive rights to raw data. The possibility of granting such rights should increase prospects for commercial investment in a remote sensing system.

(3) Authorization for the granting of exclusive licenses for the development of commercial products utilizing satellite data.

The Government may also consider the granting of exclusive rights for the development of data products, as opposed to raw data sales. As a greater range of value added products becomes economically feasible, the value of such a license rises. Examples include the commercial production of atlases, films, television news segments, and information products appealing to special interest groups.

(4) Granting of special or exclusive rights to the operator or manager of the space segment for commercial exploitation of data from NASA research sensors, NOAA operational sensors, or DMSP operational sensors.

Such rights would presumably increase the possibility of commercial return to the system. The data could still be made available to the research community at modest charge, perhaps after a time period over which the commercial value of the data had declined.

(5) Leasing of spacecraft accommodations (space, power, data handling, etc.) from the ACERSS program.

This option is the inverse of Option 2 under "Restructuring of System Costs" above, in that it aims to use the satellite bus for other Government programs, rather than to provide satellite accommodation through those programs.

(6) Permitting the use of the satellite bus for other commercial purposes.

This option does not seem to have been widely considered. However, it may be worth exploring opportunities for "piggy-back" instruments or capabilities unrelated to the main objectives of the satellite mission. One example is the provision of subscription information services that could be telemetered down with the remote sensing data to individual ground stations.

31

ACERSS Advocate to Provide Single Point of Contact

The options described above collectively involve a number of Federal agencies, particularly NOAA, NASA, and DoD. Historically, these agencies, because of differing goals and missions, have not cooperated fully in providing a single advocacy for satellite remote sensing.

For example, NOAA provides funding for the present Landsat program and sponsors the operation of polar orbiting environmental satellites. Although these two programs share some basic technical characteristics, they are uncorrelated even within this single agency through lack of Government-wide policy initiatives. The R&D capabilities of NASA in sensor development are no longer available to the Landsat program. The Department of Defense has a keen interest in the future of Earth remote sensing generally, purchases increasing amounts of civil remote sensing data, and plays a dominant role in the procurement of U.S. launch services. Yet it does not intend to provide future ACERSS support.

The present fragmentation of effort and resources is highly detrimental to the ACERSS program. In order to exploit the economic benefits offered by combinations of the options listed above, there will need to be established a strong advocate entity within the U.S. Government for ACERSS funding and policy decisions. This entity must have the responsibility and authority to cut across departmental and agency lines to serve as a single point of contact for ACERSS and all future civil remote sensing activities. In addition, this entity could represent the United States in international negotiations on remote sensing issues such as data format standards. Such action would appear to be a prerequisite for the continued effectiveness of the program.

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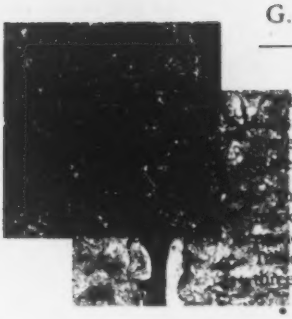
G. RECOMMENDATIONS



A sensor suite including an advanced Multispectral Linear Array will be highly responsive to market
32 *demand in the 1990s. United States participation in an international consortium will lower required U.S. investment in the ACERSS space segment.*

he recommendations of this study are driven by two primary objec-: to increase the revenues to an Advanced Civil Earth Remote Sensing em, and to reduce the investment in the space segment by the United s Government.

ncreased revenues are best achieved by an advanced sensor suite that onds to market demand for advanced technological capabilities, in icular, high spatial resolution (5 m or better). Options 4 and 5 of e 5 best meet these objectives through provision of the following ree sensors:

- A stereoscopic Multispectral Linear Array (MLA) offering 5m spatial resolution or better. Along track stereo capability is necessary to serve a significant market for accurate topographic mapping.

- An Enhanced Thematic Mapper (ETM) offering 30m spatial resolution, similar to the ETM scheduled for Landsat 6. The ETM provides sufficiently high spatial resolution for many important markets and furnishes data continuity in spectral bands of proven utility.

- A broad swath imaging radiometer offering moderate spatial resolution (1 km) and daily coverage, similar to the SeaWIFS instrument scheduled for Landsat 6 or the AVHRR instrument aboard the present NOAA polar orbiting satellites.

This sensor suite represents a good balance between capabilities and cost. However, the primary avenue for cost reduction is provided by Option 5: sharing of ownership of the space segment.

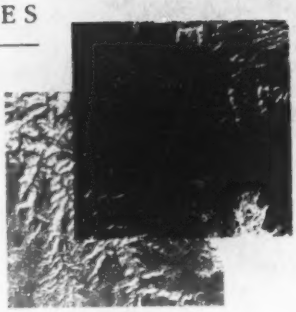
We also recommend:

- A controlling 40% United States ownership share in an international ACERSS consortium. U.S. Government investment is thereby reduced substantially, while a 40% ownership share—assumed the dominant share within a multinational partnership—will provide sufficient United States influence and control to protect U.S. interests and policy priorities.

- Establishment of a strong ACERSS advocate within the U.S. Government to provide a single point of contact for ACERSS funding decisions, policy formulation, and management oversight.

- Continuation of the present experiment for private sector management of the ACERSS space segment through prompt initiation of a competitive selection process.

APPENDICES



33

APPENDIX 1. MARKET SEGMENT DATA

Table 6 delineates the major markets for the base year 1988 and for the year 2000 in the high growth scenario. Tables 7 and 8 provide detailed market profiles for the two principal markets, the U.S. Government and private industry.

Table 6. Projected Growth in Civil Markets.

Market ($M)	1988			2000		
	Raw Data Sales	Value Added Products	Totals	Raw Data Sales	Value Added Products	Totals
Private Industry	**5**	**7**	**12**	**68**	**147**	**215**
U.S. Government	5	5	10	33	17	50
Foreign	17	39	56	87	203	290
State & Local	-	-	1	4	8	12
Academia	-	-	-	3	1	4
Nonprofit	-	-	-	-	-	1
TOTAL DATA SALES	**27**	**52**	**79**	**197**	**374**	**572**
Ground Station Fees	12	-	12	26	-	26
TOTAL REVENUES	**39**	**52**	**91**	**223**	**374**	**598**

Total Raw Data Market Profile ($ 1000)													
Agency	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Department of Agriculture	1700	1880	2100	2360	2710	3040	3410	3820	4380	4920	5510	6180	6920
Department of Commerce-NOAA	4	4	13	6	6	7	8	9	10	11	28	14	16
Department of Energy	8	9	10	11	13	14	16	19	21	23	26	29	33
Department of the Interior	520	620	750	900	1080	1290	1660	1870	2240	2680	3220	3870	4640
Department of Transportation	3	4	4	5	8	10	11	26	31	37	44	52	62
Environmental Protection Agency	2	2	2	2	3	3	3	4	5	5	6	7	8
NASA - Earth Science & Applications	5	5	6	6	7	8	9	10	11	12	14	16	18
Agency for International Development	400	450	500	560	700	840	970	1210	1450	1670	1870	2090	2350
TOTAL	**2,642**	**2,974**	**3,385**	**3,850**	**4,527**	**5,212**	**5,977**	**7,068**	**8,158**	**9,358**	**10,718**	**12,258**	**14,047**
Total Value Added Plus Raw Data Market Profile ($ 1000)													
Agency													
Department of Agriculture	2100	2350	2630	2950	3390	3800	4260	4900	5490	6150	6890	7720	8650
Department of Commerce-NOAA	5	6	16	7	8	9	10	11	12	14	36	17	19
Department of Energy	10	11	13	14	16	18	20	23	26	29	33	37	41
Department of the Interior	800	960	1150	1380	1660	1990	2390	2870	3440	4130	4960	5950	7140
Department of Transportation	5	7	8	9	16	19	22	91	61	73	87	104	124
Environmental Protection Agency	5	6	6	7	8	10	11	14	16	18	20	23	26
NASA - Earth Science & Applications	5	6	8	7	8	9	10	11	12	14	16	17	19
Agency for International Development	2000	2240	2510	2810	3510	4210	4840	6050	7280	8350	9350	10470	11730
TOTAL	**4,930**	**5,585**	**6,330**	**7,184**	**8,616**	**10,064**	**11,563**	**13,930**	**16,318**	**18,778**	**21,391**	**24,338**	**27,750**

Table 7. U.S. Government Market Profile, High Growth Scenario.

Total Raw Data Market Profile ($ 1000)

Market Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture/Agribusiness	200	250	310	390	530	680	880	1200	1620	2180	2840	3690	4800
Engineering & Construction	400	460	530	610	780	950	1140	1540	1930	2320	2780	3340	4010
Extraction	2650	2500	7070	7850	9020	10020	11120	13900	15420	17120	19000	21090	23410
Fisheries	0	0	0	0	10	10	10	20	30	40	50	70	90
Forestry	360	400	460	530	640	730	840	1050	1260	1520	1820	2090	2410
Insurance	0	130	150	180	230	290	360	470	610	790	1030	1340	1600
Investment	90	140	160	180	220	280	300	370	450	540	660	790	940
Legal	0	0	480	550	690	900	1080	1400	1750	2190	2740	3420	4110
Mapping	400	420	440	520	650	780	940	1220	1530	1910	2390	2860	3440
Mass Markets	10	10	20	20	30	40	50	70	90	120	150	200	280
Media	50	50	60	90	130	190	280	630	910	1330	1920	2790	3910
Real Estate	10	20	20	20	30	50	60	90	130	180	250	350	490
Shipping	0	0	0	0	500	580	630	790	950	1140	1250	1380	1520
Simulation	20	290	330	380	490	610	730	990	1290	1670	2090	2610	3140
Utilities	90	100	1080	1300	1840	2300	2870	4030	5230	6540	8170	9800	11770
Waste Management	100	120	140	180	280	350	440	640	860	1120	1410	1760	2200
TOTAL	**4,380**	**4,890**	**11,250**	**12,880**	**16,030**	**18,740**	**21,710**	**28,410**	**34,000**	**40,710**	**48,550**	**57,500**	**68,100**

Total Value Added Plus Raw Data Market Profile ($ 1000)

Market Segment	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Agriculture/Agribusiness	1000	1250	1560	1950	2630	3420	4280	5990	8090	10920	14200	18460	24000
Engineering & Construction	1000	1150	1320	1520	1900	2380	2880	3860	4830	5800	6960	8350	10020
Extraction	4500	5000	10100	11210	12890	14310	15880	19850	22030	24450	27140	30130	33440
Fisheries	25	25	25	25	40	50	70	100	140	190	260	340	440
Forestry	1200	1340	1540	1770	2120	2440	2810	3510	4210	5050	6060	6970	8020
Insurance	0	840	770	920	1150	1440	1800	2340	3040	3950	5140	6680	8020
Investment	450	700	800	920	1090	1290	1510	1830	2240	2710	3290	3930	4710
Legal	0	0	2400	2760	3450	4490	5390	7010	8760	10950	13690	17110	20530
Mapping	2000	2100	2210	2610	3260	3910	4690	6100	7630	9540	11930	14320	17180
Mass Markets	400	480	620	810	1050	1370	1780	2310	3000	3900	5070	6590	8570
Media	230	270	320	440	630	950	1390	3150	4570	6630	9620	13960	19540
Real Estate	40	50	60	80	110	150	210	300	420	590	830	1160	1620
Shipping	0	0	0	0	2500	2880	3170	3960	4750	5700	6270	6900	7590
Simulation	100	1950	2180	2500	3250	4070	4890	6600	8580	11150	13940	17430	20920
Utilities	150	170	1800	2160	3060	3830	4790	6710	8720	10900	13620	16340	19610
Waste Management	500	600	720	900	1310	1770	2210	3200	4320	5620	7030	8790	10990
TOTAL	**11,595**	**15,725**	**26,425**	**30,575**	**40,440**	**48,750**	**57,730**	**76,820**	**95,330**	**118,050**	**145,050**	**177,460**	**215,200**

Table 8. Private Industry Market Profile, High Growth Scenario.

APPENDIX 2. SENSOR MARKET WEIGHTING

The data products listed in Table 9 are those that address a total of 25 remote sensing application areas identified as needs of the markets shown in Table 6. These applications are listed in Table 10, along with the data products. The numerical entries reflect the relative size of the markets that the applications serve. Summing the columns yields a market-weighted score for each product.

This is shown at the bottom of the table along with key technical parameters for each product. Each candidate sensor type was evaluated to determine its ability to provide the products needed. An example of this evaluation is shown in Table 9 for the URV/IR sensor type. The "Market" column contains the market-weighted product scores from Table 10. Values in the "Sensor" column are a measure of the sensor's ability to meet the performance requirements of the products. The right-most

36 **Table 9. Market Weighted Score For URV/IR Sensor Type.**

/ Product		Market	Sensor	URV/IR Sensor
		Market Weighted Product Score	Sensor Product Performance Score	Market Weighted Sensor Score
1	Land Use/Cover (Level 1/2: Coarse Mapping)	252	9	2268
2	Land Use/Cover (Level 3/4: Fine Mapping)	258	10	2580
3	Ecological Life Zones	118	0	0
4	Crop/Forest Yields	35	7	245
5	Vegetation Stress	128	10	1280
6	Leaf Area Index	163	10	1630
7	Primary Productivity	136	0	0
8	Surface Structure/ Drainage	271	9	2439
9	Surface Minerals /Soil Maps	206	6	1236
10	Digital Terrain Models	341	9	3069
11	Geomagnetic /Geopotential Fields	52	0	0
12	Soil Moisture	275	0	0
13	Snow Cover	181	0	0
14	Bathymetry	70	9	630
15	Pollution Indices	58	9	522
16	Turbidity	58	8	464
17	Vertical Profiles	100	0	0
18	Cloud Cover	44	0	0
19	Precipitation	252	0	0
20	Visibility	27	0	0
21	Gas Concentration/Variation	27	0	0
22	Thermal Contours	20	0	0
23	Salinity	49	0	0
24	Sea Surface Winds	49	0	0
25	Sea State	72	0	0
26	Ice Type/Extent	72	7	504
27	Pretty Pictures	8	10	80
28	Perspective View	118	8	944
29	Quick Look	88	8	704
30	Image Maps	235	8	1880
31	Ortho Maps	299	7	2093

column shows a market- column shows a market weighted score for each product; the sum of this column represents the URV/IR's market-weighted score. All other candidate sensor types were evaluated similarly and the results compared. Five types stood out as having the highest scores. Evaluation of military markets and applications yielded similar results.

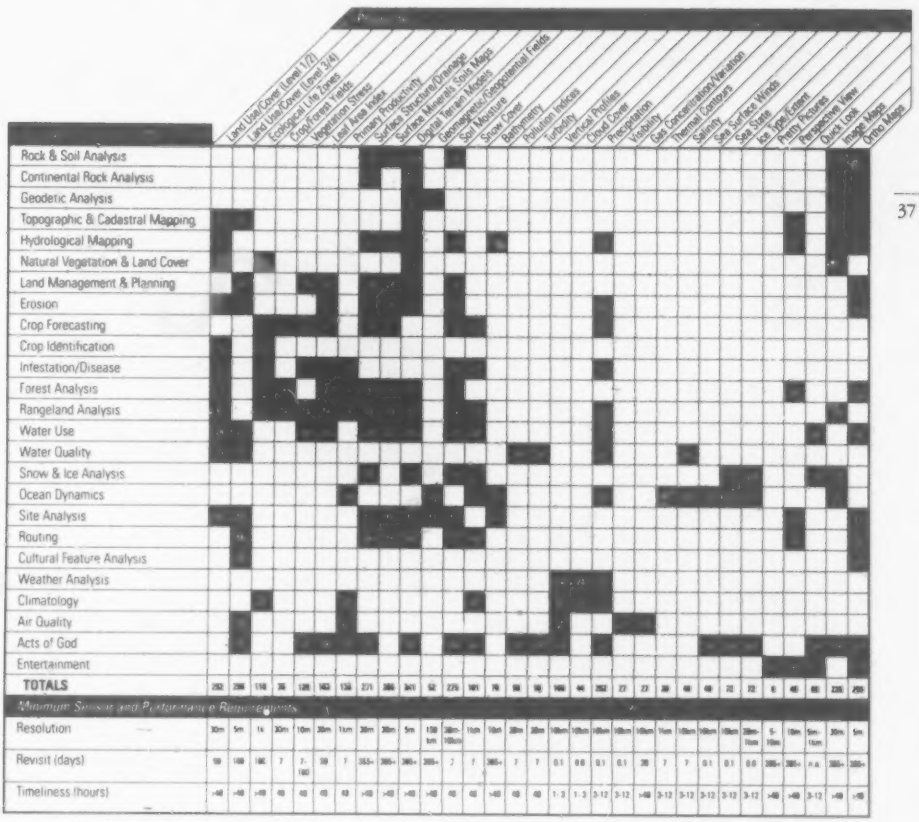

Land Use/Cover (Level 1/2)
Land Use/Cover (Level 3/4)
Ecological Life Zones
Crop/Forest Yields
Vegetation Stress
Leaf Area Index
Primary Productivity
Surface Structure/Drainage
Surface Mineral Soil Maps
Digital Terrain Models
Geomagnetic/Geopotential Fields
Soil Moisture
Snow Cover
Bathymetry
Pollution Indices
Turbidity
Vertical Profiles
Cloud Cover
Precipitation
Visibility
Gas Concentration/Variation
Thermal Contours
Salinity
Sea Surface Winds
Sea State
Ice Type/Extent
Precip. Pictures
Perspective View
Quick Look
Image Maps
Ortho Maps
Rock & Soil Analysis
Continental Rock Analysis
Geodetic Analysis
Topographic & Cadastral Mapping
Hydrological Mapping
Natural Vegetation & Land Cover
Land Management & Planning
Erosion
Crop Forecasting
Crop Identification
Infestation/Disease
Forest Analysis
Rangeland Analysis
Water Use
Water Quality
Snow & Ice Analysis
Ocean Dynamics
Site Analysis
Routing
Cultural Feature Analysis
Weather Analysis
Climatology
Air Quality
Acts of God
Entertainment
TOTALS
252 256 110 35 128 163 135 271 266 241 52 229 101 70 58 98 160 44 252 27 27 20 60 60 22 22 6 40 40 235 259
Minimum Sensor and Performance Requirements
Resolution
30m 5m 1k 30m 10m 30m 1km 30m 30m 5m 150 km 30m-100km 1km 10km 20m 20m 100m 100m 100m 100m 1km 100m 100m 20m-1km 5-10m 10m 5m-1km 30m 5m
Revisit (days)
10 160 180 7 7-180 10 1 365+ 365+ 240+ 365+ 7 1 365+ 7 7 0.1 0.6 0.1 0.1 20 7 1 0.1 0.1 0.6 365+ 365+ n.a. 365+ 365+
Timeliness (hours)
>48 >48 >48 48 48 48 48 >48 >48 >48 >48 48 48 >48 48 48 1-3 1-3 3-12 3-12 >48 3-12 3-12 3-12 3-12 3-12 >48 >48 3-12 >48 >48

Table 10. Market Weighting of Data Products.

APPENDIX 3. NET PRESENT VALUES

Overview. All of the ten space segment sensor/ownership options listed in Table 5 fail the first test of commercial viability, since revenues fall short of investment in every case. Evaluating the investment requirements in light of the revenue streams and the time value of money shows the true cost of these options. A commercial investor seeks competitive returns in compensation for assuming risk. While expected rates of return vary, net present value (NPV) was calculated for illustration based on a 40% return—a rate typically expected by commercial investors in ground-based ventures.

Table 11 shows the results: options 1, 3, and 5—respectively, the single-sensor U.S. option, reflight of the Landsat 6 sensors by an international consortium, and the advanced international option—are the least costly. Yet they would each cause space segment investors to lose approximately $100 million when compared to three-year investment alternatives that return 40% per year. Alternatively, this can be interpreted as the additional U.S. government investment that would be required to privatize the space segment, i.e., attract private investment. (Option 5, recommended for U.S. Government consideration, shows the least negative NPV under a non-privatized—0% return—approach)

Calculation. In a commercial approach, private investors provide the U.S. space segment investment share in return for the U.S. share of the three year revenue stream. The investment, assumed to be made in 1995, constitutes a negative contribution to the transaction. The revenues from 1996, 1997, and 1998, discounted by factors depending on the required rate of return on investment and the year in which the revenue is realized, yield positive contributions. The sum of the four contributions is the NPV of the transaction:

$$NPV = (-)\ \text{Investment}\ (1995) + \frac{\text{Rev}\ (1996)}{(1+r)} + \frac{\text{Rev}\ (1997)}{(1+r)^2} + \frac{\text{Rev}\ (1998)}{(1+r)^3}$$

where r is the rate of return. Investors seek transactions that maximize NPV. They will reject transactions with negative NPV, remain indifferent to transactions with zero NPV, and compare transactions having positive NPV with other viable investment opportunities.

Table 11 presents the net present values of the ten implementation options for a required rate of return of 40%. For comparison, a rate of 0% is included. Entries for U.S. investment are taken from column C of Table 5. U.S. revenues for each year have been calculated from the total market revenues given in Table 1 and the U.S. ownership and market shares given in Table 5.

The NPV entries in Table 11 corresponding to zero rate of return are simply equal to investment less the three year revenue sum. Discounting of the revenue stream by 40%—a typical return expected by investors in ground-based ventures—reduces its value to about 50% of the revenue sum.. The NPV entries for a 40% rate of return are consequently more

negative than those for a zero rate of return. Additional investments, equal to the magnitudes of the NPV entries, would have to be provided from another source to begin to make these options worthy of investor attention.

In reality even greater additional investment than this would be required. The simplified NPV calculation presented here reflects market risk only. It neglects technical risk and liability exposure. Private investors would insist upon insurance against these and other perils at substantial additional cost. Moreover, the technical risk of all space operations is perceived as very high by the investment community. A rate of return much greater than 40% may be needed to surmount this psychological barrier, further depressing net present value.

The U.S. Government might attempt to attract private investors to the space segment of ACERSS by promises of future payments—for example, raw data purchases by Federal agencies. If this were the only channel for additional investment, Table 11 Option 10, shows that Federal raw data purchases reaching $150 million per year over 3 years would probably be needed to gain investor attention. This an amount almost five times greater than the $33 million projected in the high growth scenario for the year 2000 (see Table 6). In view of the Landsat 6 experience, investors would be expected to discount steeply promises to make such payments unless they were enforced by Congressional legislation and budget allocation.

39

Option	U.S. Space Segment Investment $M: 1995	U.S. Space Segment Revenues $M: 1996	1997	1998	Net Present Value $M: 7% Rate of Return	Net Present Value $M: 40% Rate of Return
1	106	4.6	5.0	5.5	-90.9	-98.1
2	310	27.3	30.0	33.1	-219.6	-263.1
3	124	14.6	16.0	17.6	-75.8	-99.0
4	402	50.9	58.8	67.5	-224.8	-311.0
5	161	25.4	29.4	33.8	-72.4	-115.6
6	201	4.1	4.5	5.0	-187.4	-194.0
7	161	5.5	6.0	6.6	-147.4	-151.6
8	402	31.8	36.7	42.3	-291.2	-345.2
9	322	33.1	38.2	43.9	-206.8	-262.9
10	516	35.6	41.2	47.3	-391.9	-452.4

Table 11. Commercial Viability of ten space segment implementation options.

APPENDIX 4. TERMINOLOGY

Key Concepts and Terms

Benefit ratio—The ratio of U.S. space segment revenues to U.S. space segment investment in an Advanced Civil Earth Remote Sensing System.

Earth Observing System (Eos)—A long-lived Earth observatory in polar orbit providing for integrated research instrument suites from the United States and other nations, to operate from 1995 onward, as part of the international Space Station program.

Ground segment (of a remote sensing system)—Ground receiving stations and the value added industry. It is assumed in the present study that the owner/operator of the space segment bears all costs of domestic ground stations and collects access fees from foreign ground stations.

Open Skies policy—The requirement that Earth remote sensing data be made available to all potential users on a nondiscriminatory basis.

40

Remote sensing—Reference to measurements made at a distance from the object or material measured. In the present study, only satellite remote sensing is considered.

Space segment (of a remote sensing system)—Launch vehicle, sensors, and spacecraft, together with satellite command, control, and communications.

Space segment investment—Costs of the space segment plus all costs and expenses of domestic ground stations, including construction and operation.

Turnaround time—The time elapsed between the acquisition of remote sensing data by the sensor and its delivery to the user.

Value added industry—That component of the ground segment that provides digital and analog data enhancement, data analysis, interpretation of remotely sensed information, and the marketing, sale, and distribution of that information to end users. It includes the computer system software and hardware that allow these users to perform the enhancement and analytical functions themselves.

Acronyms and Abbreviations

ACERSS: Advanced Civil Earth Remote Sensing System

ADV: Advanced

ALT: Altimeter

AMSR: Advanced Microwave Scanning Radiometer

AMSU: Advanced Microwave Sounding Unit

AVHRR: Advanced Very High Resolution Radiometer

BILAT: Bilateral

BRS: Brazilian Remote Sensing satellite

CCDS: Center for the Commercial Development of Space

CNES: Centre National d' Études Spatiales
COSMOS: Soviet satellite series
DMSP: Defense Meteorological Satellite Program
DoD: Department of Defense
DoE: Department of Energy
DoI: Department of the Interior
DoT: Department of Transportation
Eos: Earth Observing System
EOSAT: Earth Observation Satellite Company
EPA: Environmental Protection Agency
ERS: Earth Remote Sensing satellite (ESA)
ESA: European Space Agency
ESTAR: Electronically Steered Thinned Array Radiometer
ETM: Enhanced Thematic Mapper
Geosat: Geodesy Satellite (USA)
GMS: Geostationary Meteorological Satellite (Japan)
GOES: Geostationary Orbiting Environmental Satellite
HFMR: High Frequency Microwave Radiometer
HIRS: High resolution Infrared Radiation Sounder
HRV/IR: High Resolution Visible/Infrared
INMARSAT: International Maritime Satellite Organization
INSAT: Indian National Satellite
INTELSAT: International Telecommunications Satellite Organization
INTL: International
IRS: Indian Remote Sensing satellite
IRS: Infrared Sounder
ISY: International Space Year (1992)
JERS: Japan Earth Remote Sensing satellite
Landsat: Land Remote Sensing Satellite (USA)
LFMR: Low Frequency Microwave Radiometer
Lightsat: A low-weight, low-cost satellite
LS: Landsat (USA)
Meteosat: Meteorology Satellite (ESA)

MLA: Multispectral Linear Array
MODIS: Moderate resolution Imaging Spectrometer
MOS: Marine Observation Satellite (Japan)
MRIR: Medium Resolution Imagery Radiometer
MRV/IR: Moderate Resolution Visible/Infrared
MS: Microwave Sounder
NASA: National Aeronautics and Space Adminstration
NATO: North Atlantic Treaty Organization
NOAA: National Oceanic and Atmospheric Administration
NPV: Net Present Value
OCP: Office of Commercial Programs (NASA)
POES: Polar Orbiting Environmental Satellite
R&D: Research & Development
RADARSAT: Canadian Radar Satellite
RAR: Real Aperture Radar
SAR: Synthetic Aperture Radar
SCATT: Scatterometer
SeaWIFS: Sea Wide Field Sensor
Sojuzkarta: Soviet mapping organization
SPOT: Satellite Pour l'Observation de la Terre (France)
SS: Space Station
SWIR: Short Wavelength Infrared
TDRSS: Tracking and Data Relay Satellite System
TIR: Thermal Infrared
TM: Thematic Mapper
TOPEX/Poseidon: Ocean Topography Experiment (NASA/CNES)
URV/IR: Ultrahigh Resolution Visible/Infrared
USDA: United States Department of Agriculture
V/NIR: Visible/Near Infrared

APPENDIX 5. FURTHER READING

SPACE COMMERCE: AN INDUSTRY ASSESSMENT (U.S. Department of Commerce, Washington, D.C., May 1988)

SPACE-BASED REMOTE SENSING OF THE EARTH: A REPORT TO THE CONGRESS (National Oceanic and Atmospheric Administration, United States Department of Commerce and National Aeronautics and Space Administration, Washington, D.C., September 1987)

SYSTEM CONCEPT FOR WIDE-FIELD-OF-VIEW OBSERVATIONS OF OCEAN PHENOMENA FROM SPACE. Report of the Joint EOSAT/NASA SeaWIFS Working Group (Earth Observation Satellite Company, Lanham, Maryland, August 1987)

LINKING REMOTE-SENSING TECHNOLOGY AND GLOBAL NEEDS: A STRATEGIC VISION. Space Applications Advisory Committee of the NASA Advisory Council, Parts 1 and 2 (National Aeronautics and Space Administration, Washington, D.C., 1987)

PROCEEDINGS OF THE CONFERENCE AND WORKSHOP ON REMOTE SENSING APPLICATIONS: COMMERCIAL ISSUES AND OPPORTUNITIES FOR SPACE STATION, (American Society for Photogrammetry and Remote Sensing, Falls Church, Virginia, 1987)

REMOTE SENSING YEARBOOK. Ed. A. Cracknell and L. Hayes (University of Dundee, Dundee, Scotland, U.K., 1987)

COMMERCIAL APPLICATIONS AND SCIENTIFIC RESEARCH REQUIREMENTS FOR THERMAL-INFRARED OBSERVATIONS OF TERRESTRIAL SURFACES. Report of the Joint EOSAT/NASA Thermal Infrared Working Group (Earth Observation Satellite Company, Lanham, Maryland, August 1986)

44

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Mr. SCHEUER. We will have questions from the panel up here after all three witnesses are finished, but I just want to ask you one question, Mr. Meier.

You mentioned that as the program presently stands a company would lose $100 million over three years compared to a 40 percent return.

Could you elaborate on what that 40 percent return means?

Mr. MEIER. Yes. When we evaluated the commercial viability of the complete remote sensing operation, we evaluated it as an investor would. How would you allow the investor to invest in that opportunity. The investor is investing his money with the expectation of receiving a 40 percent return.

Mr. SCHEUER. A 40 percent return how? You don't mean a 40 percent return annually?

Mr. MEIER. As a commercial investment in a normal commercial enterprise, an investor might expect a 40 percent return.

Mr. SCHEUER. Annually?

Mr. MEIER. Over the term of the investment.

Mr. SCHEUER. You mean over a three-year period they would expect something like a 16 or 17 percent return each year, a cumulative return of 40 percent? Is that what you're saying?

Mr. MEIER. That's correct.

Mr. SCHEUER. That's reasonable. A 40 percent return annually would have been a bit beyond the pale. I'm glad for that clarification.

Dr. Robert F. Brammer, TASC, The Analytic Science Corporation, please take your five or six or seven minutes and chat with us, hopefully informally, and liberate yourself if you can from the printed page and don't hesitate to advert to anything you've heard this morning from either the panel up here or the panels down there.

STATEMENT OF DR. ROBERT F. BRAMMER, THE ANALYTIC SCIENCE CORPORATION, READING, MASSACHUSETTS.

Dr. BRAMMER. Thank you, Mr. Chairman. I'll do my best to liberate myself.

Thank you for the opportunity to address this rather critical issue of the future of Landsat. I have submitted as my written testimony the executive summary of our report entitled "A Study of an Advanced Civil Earth Remote Sensing System," prepared last year for the Department of Commerce. Working with us in writing that report were CSP Associates and BLA.

The oral comments which I wish to make here summarize some important points from that report.

First, by way of background, TASC is one of the nation's leading applied technology companies. They have been a pioneer in the use of multi-spectral land remote sensing data in a number of applications for both industry and government. We integrate the use of the land remote sensing data with other satellite information and create a number of products, including those for crop forecasting, mapping and cartography, natural resource assessment, geological surveys, news media, and government applications.

Our customers are a very diverse group, including ABC News, National Geographic, many of the oil majors, major food and grain companies, and several government agencies.

Mr. SCHEUER. Do you have on your list any government agencies or private sector users involved in resource management, in forest management, or crop management?

Dr. BRAMMER. We have done research and operational data services for some of the agricultural companies interested in assessing areas in remote parts of the world which might not be readily accessible through ground surveys, looking for areas of cultivation and status of the crops.

Mr. SCHEUER. Would you have as clients, let us say, the Department of the Interior in connection with their managing park lands and the vast natural resources; perhaps the Environmental Protection Agency; perhaps the Department of Energy? All of those might be customers for you in terms of resource management.

Dr. BRAMMER. Yes, sir, they might have been. To date, they have not.

Mr. SCHEUER. Please proceed.

Dr. BRAMMER. We have been in the satellite remote sensing marketplace for more than a decade and it is from this hands-on perspective that we come here today to talk about the future of Landsat.

There are three principal conclusions from our report. First, a fully commercial, independent Earth remote sensing business may become viable early in the next century. By then, with enough effort in market development and education, the market may be large enough and diverse enough to support a fully independent commercial enterprise. However, projected market revenues will not support a fully viable commercial business during the 1990s.

It is well known in this community that early market projections were much too optimistic and the failure to have these markets develop over the past several years is due in part to uncertainties in the U.S. Landsat program during the past decade and to the lack of a sufficient focused effort in market development and education.

The second conclusion, for this industry to be financially viable, its revenues from preprocessed data sales must be significantly greater than those now achieved by EOSAT and SPOT. Increased revenues will be available when the data become more valuable to end users. The value of the data can be much enhanced with increased spatial resolution, much more timely delivery, more frequent satellite revisits, and other feasible technical improvements.

Mr. Chairman, I would like to note that the aspects of timely delivery and coverage are at least as important in creating these markets as questions related to the type of sensor or the number of spectral bands.

Finally, the third principal conclusion, our recommendation was that a U.S.-based business should be structured during the 1990s as a government-private sector joint venture with progressively increasing commercial investment and decreasing government involvement until it evolves into a fully private enterprise.

Let me close with four observations based on our many years of experience in value-added information services from satellite remote sensing data.

First, any business—and this business in particular—demands reliable and continuous sources of data. Predictable continuity is imperative and no business can grow and prosper with gaps in coverage both in space and time. In addition to the reliability and the continuity, we have to talk about timeliness. Waiting six months or even six weeks for this imagery can kill its value in the marketplace.

Second, as in any business, new markets can develop or be created as the products improve, and so it is in this business. We in the value-added service industry can create significant new markets if the data sources improve, providing better resolution, more timely access, and distribution of the preprocessed data, and better access, better technology for the ground processing and delivery systems. We need to rely increasingly on electronic communications rather than archiving and shipping magnetic tapes and data.

Third, with respect to the U.S. government as a market, many government agencies have legitimate needs for remotely sensed data and information products. These needs are no different from other commercial products, such as computers and paper and other products that these agencies need to carry out their mission. We must overcome the perception that the purchase of remotely sensed data and information products is some kind of a government subsidy.

Finally, we need constancy in government policy and budgeting. To date, government policies in satellite remote sensing have varied greatly. For example, data from the Polar Orbiting Environmental Satellites is largely controlled by the government with very limited access of the data to the private sector. Data from the Geostationary Meteorological Satellites are accessed both directly by the private sector firms as well as the government; and data from the Land Remote Sensing Satellites, like Landsat, is in some primitive state of commercialization where control rests with the private sector.

These differences in policies for managing the data are derived largely, in my opinion, from outdated, perceived differences in their use. Much of our business deals with the integration of these data types to create value-added information products for our customers.

Of course, budget uncertainties greatly inhibit planning and investment by the private sector and that, in our opinion, has inhibited the growth of the marketplace.

In conclusion, Mr. Chairman, I am very optimistic about the potential of the technology to create value for a number of commercial applications, but we have to overcome the policy and the funding uncertainties that have limited the growth of this industry in the United States over the past two decades.

Thank you very much.

[The prepared statement of Dr. Brammer follows.]

TR-5629-1

A STUDY OF AN ADVANCED CIVIL EARTH REMOTE SENSING SYSTEM

EXECUTIVE SUMMARY

12 August 1988

FINAL REPORT

Prepared under:

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Federal Building #4, Room 2051
Suitland, MD 20233

Prepared by:

Arthur Bass
Steven Berner
Allen Coburn
Al Gargiulo
Brad Meslin
Mark Oderman
Marc Vaucher

Approved by:

Paul Janota

THE ANALYTIC SCIENCES CORPORATION
55 Walkers Brook Drive
Reading, Massachusetts 01867

FOREWORD

The development of this report was conducted under contract with the Department of Commerce to obtain an independent analysis for the Government to consider in preparing its action plan for an advanced civil earth remote sensing system. Any opinions, finding, conclusions, or recommendations for the Government to consider that are expressed in this report are those of the contractor and do not reflect the policies or approval of the United States Government.

1. EXECUTIVE SUMMARY

1.1 STUDY OBJECTIVES

Looking beyond LANDSAT 6, the Congress appropriated FY 1988 funds for technical studies of options to commercialize the future U.S. civil remote sensing program. The House Appropriations Committee directed the Department of Commerce (DOC)

> "....to conduct a study of options for subsequent remote-sensing activities, taking into account data markets and launch options....to examine opportunities for government/industry partnership with substantial industry investment, participation by other government agencies, and an international cooperative partnership....this study will provide the basis on which the Congress can determine policy of the future of any advanced commercialized system."

The Analytic Sciences Corporation (TASC) was awarded a DOC contract for a `comprehensive' study taking into account: the present and foreseeable trends in the domestic and international markets for earth remotely sensed data and value-added information products; 1990s technology projections for spacecraft, sensors, data management, and communications; and options for substantial private investment.

TASC ,the Prime Contractor for this study contract, was responsible for two study elements, Market Survey and Data Processing Technology. CSP Associates (CSP), a subcontractor, was responsible for Financing Options and Space Technology. Berner Lanphier & Associates (BLA), a second subcontractor, was responsible for Sensor Technology and Launch Options.

The TASC team's goal was to evaluate technical, financial and organizational options which could maximize the role of the private sector in all aspects of the development and operation of a Civil Earth Remote Sensing System (CERSS), while progressively minimizing Government support.

1.2 TEAM QUALIFICATIONS

The team of TASC, CSP and BLA brings to this study unique complementary experience and excellent marketplace credentials

in applications of multi-spectral remote sensing data to civil and national security requirements. Together, this team has extensive understanding of (a) the domestic and international markets that will drive a future commercial remote sensing business; (b) the various enabling technologies that will make such a system possible: sensors, spacecraft, launch alternatives and data processing; and (c) the numerous financial, organizational and policy issues to be resolved for a viable commercial entity. We were able to organize our collective understanding and begin the study effort with no required 'start-up' time.

TASC, one of the nation's leading applied technology companies, is a recognized national leader in use of multispectral satellite data for applications to industry and Government. In numerous programs for the Government, TASC develops and implements state-of-the-art systems to process satellite remote sensing data and create value-added information. TASC has also pioneered in the use of airborne, Landsat and SPOT earth remote sensing data to create innovative new commercial products for a variety of customers, including products for national security mission planning and simulation; crop forecasting; mapping/cartography; natural resource assessment; geological surveying; media; and similar applications.

At the same time, TASC is well known in the commercial world for its pioneering value-added environmental satellite information products. Through its subsidiary, WSI, TASC operates one of the nation's largest commercial distribution services for real-time distribution of value-added environmental satellite data and information products.

CSP Associates is a leading aerospace business consulting firm that provides business planning, market and financial analysis, and program support services to Government and industry in areas of civil, commercial and national security space programs.

BLA is a technology and engineering consulting firm that assists Government and aerospace industry customers in evaluating the business, policy and national security implications of advanced technologies for remote sensing and image processing systems, satellite communications, space technology assessments and space launch vehicle costs.

1.3 OUR STUDY METHODOLOGY

We Adopted a 'Market Characterization' Approach

The theme we adopted for this comprehensive study was to explore the viability of a commercial CERSS from a market-driven (not technology-driven) perspective. We started from the fundamental premise that successful commercialization demands realistic characterization of the future market.

To assess prospects for commercial earth remote sensing in the 1990s and beyond, we did a 'future market characterization', not a conventional 'market survey'. This choice was driven by TASC's own success in creating a commercial market for data from environmental satellites. When TASC first decided to enter this market, it was small and fragmented. (If we had carried out a 'survey' of the market at that time, it would have shown that very few of our current customers would have supported the development of this market.)

From this successful commercial experience, TASC brought to this CERSS study a proven template for the actions needed to develop a vigorous market in space-based earth remote sensing. One clear conclusion from our own successful experience was the importance of understanding market trends and future market needs from the perspective of its key decisionmakers, those who specify the demand and can pay to meet it.

This way of looking at a market is very different from a conventional 'market survey' approach - that is, a traditional statistical analysis of needs and buying habits, appropriate for a mature, large market. But market survey techniques can be misleading for a small, undeveloped market - indeed, past market surveys for the earth remote sensing business have proved almost uniformly unrealistic and overoptimistic.

Market surveys are inappropriate for a small, emerging commercial market, like the current commercial market for satellite-based earth remote sensing data and products. The user community - small, fragmented, and for the most part not very knowledgable - does not have the perspectives that would provide useful guidance for developing a successful commercial business entity. There are only a very few truly knowledgable and influential users - successful businesspeople and other "entrepreneurs" who understand the technology and its end value, who have the power to influence purchases of data,

products and services, who make policy recommendations, and who have a clear vision of the future. It is to this relative handful of key customers (or potential customers) that we must turn for the soundest guidance about market prospects.

To make successful long-range (10-15 year) projections of market revenues we need a fundamental understanding of customer needs, important trends in related technologies, and future competitive pressures in this market. Analysis of such an emerging market requires a detailed approach based on: first-hand experience; knowledge of the enabling technologies; sound business judgement; and entrepreneurial intuition. We call this approach "market characterization". It begins from conventional information sources, but "calibrates" this information with indepth interviews of key end-users and decision-makers.

Most successful marketing of new products and services is highly dependent upon judgment. It is an art, not a science.

How We Segmented the Market

We segmented the overall market for CERSS into Domestic and International components. Table 1-1 reflects the full segmentation we adopted.

The seven market segments reflect a businessperson's perspective of the market. (This was found more useful than the traditional segmentation into 'Renewable Resources' and 'Non-renewable Resources'.) We used generally similar kinds of customer requirements (data, product sets, timeliness, etc.) to group market elements into segments. For example, the separate market elements for Engineering, Construction and Mapping were grouped into one segment.

The market must also be partitioned by sensor and data needs. The analysis of prospective revenues for different market segments drives the evaluation and ultimate selection of a commercially optimal sensor package from various candidate sensor suites. Table 1-2 summarizes the principal sensor/data requirements for each market segment.

TABLE 1-1

MARKET SEGMENTATION FOR CERSS STUDY

MARKET GROUP
DOMESTIC COMMERCIAL
• RECURRING
- AGRICULTURE
- FORESTRY
- ENGINEERING/CONSTRUCTION/MAPPING
- MEDIA
• NONRECURRING
- ENERGY AND MINERALS
U.S. GOVERNMENT
- DEPARTMENT OF DEFENSE/INTELLIGENCE COMMUNITIES
- FEDERAL LAND MANAGERS AND OTHER GOVERNMENT AGENCIES
INTERNATIONAL
- FOREIGN GROUND STATIONS (ACCESS FEES, ROYALTIES)
- FOREIGN SALES

TABLE 1-2

SENSOR/DATA NEEDS BY MARKET SEGMENT

MARKET SEGMENT	SPATIAL RESOLUTION(m)	SPECTRAL RESOLUTION		STEREO	REVISIT PERIOD	TIME FROM ACQUISITION
		PRIMARY	SECONDARY			
Commercial Agriculture	5-30	VIS/NIR	SWIR/LWIR	no	week to month	days to week
Commercial Forestry	5-30	VIS/NIR	SWIR	no	month to quarter	days to weeks
Engineering/ Construction/ Mapping	5	VIS		yes	by exception	days to months
Media	5	VIS/Pan		yes	days to weeks	hours to days
Energy and Minerals	10-80	VIS/NIR/ SWIR/SAR	LWIR	yes	seasonally	days to weeks
DoD/Intelligence	5	VIS/NIR	SWIR/LWIR	yes	by exception	hours to days
Federal Land Managers and other Agencies	5-80	VIS/NIR/ Pan	SAR,MW	yes	month to year	weeks to months

VIS = visible
NIR = near infrared
SWIR = short wave infrared
LWIR = long wave infrared
SAR = synthetic aperture radar
Pan = panchromatic
MW = microwave

Our Model of a CERSS Business

In our model of the postulated business environment for earth remote sensing in the 1990s (see Fig. 1-1), we assume there will be three earth resource satellite entities (U.S., French and Japanese) that compete to sell preprocessed digital images to a number of value-added firms, who will in turn sell heavily processed, value-added information products to the final buyers. In addition, a number of larger institutions (e.g., Government agencies and universities) will buy preprocessed data to do their own value-adding. Finally, there will be international revenues derived from earth station leases, royalties and sales of preprocessed data.

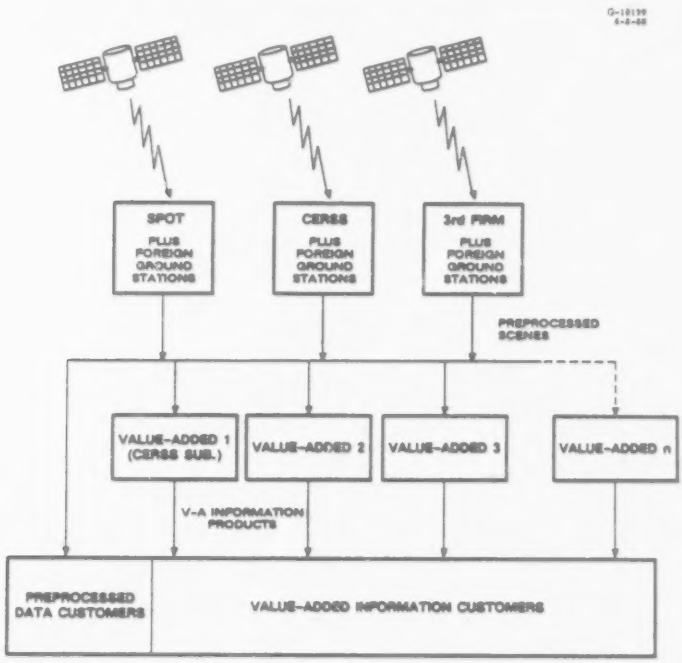

Figure 1-1 Model of the Earth Remote Sensing Business

The value-added firms can `leverage' relatively costly preprocessed data by creating more numerous information products for their customers. We postulate a subsidiary of the CERSS entity as one of the value-added firms. This subsidiary would be treated like all others with respect to the sale of preprocessed data. To be competitive, this subsidiary must not be `taxed' unfairly by its corporate owner to offset the costs of the preprocessed data; therefore, the CERSS entity must be able to sustain itself on the sales of preprocessed data alone.

We Used an Iterative Study Methodology

At its core, our study methodology was basically a simple straightforward iterative analysis (see Fig. 1-2):

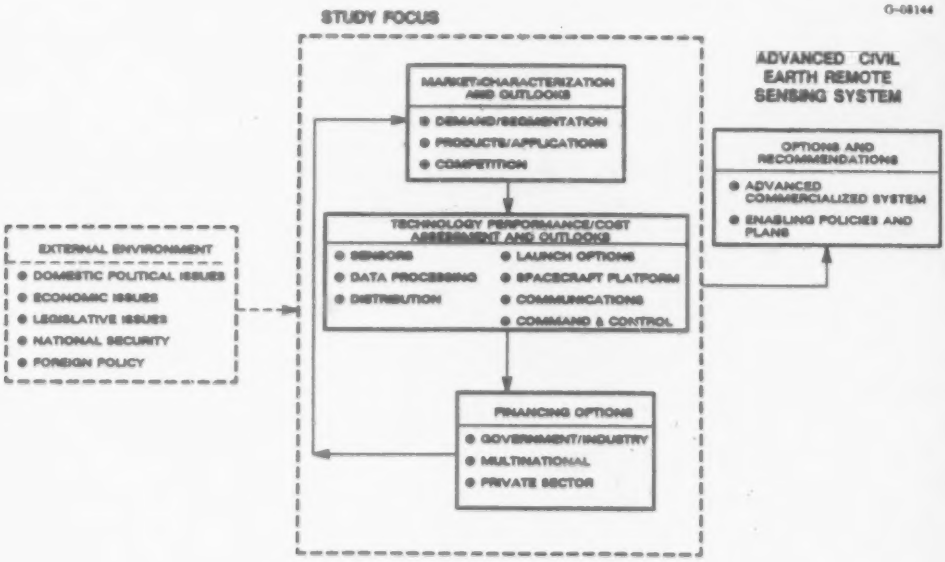

Figure 1-2 The TASC Team's Market-Driven Methodology

- Market demand and competition drive the technologies and launch options to meet the required performance and cost criteria
- Technologies (spacecraft, sensors, and data processing) and launch options drive the capital requirements and operational costs.
- Less desirable financing options force iterative reexamination, beginning anew with market demand.

Once the iterative process converges upon the best achievable ratio of projected revenues-to-costs, the analysis proceeds to a conclusion:

- Acceptable financing options lead to alternative organizational options
- A preferred organizational option leads to an implementation plan
- Implementing actions lead also to recommendations on legal, regulatory, and policy issues.

Our study concludes with recommendations for the Government to consider that may lead to a commercially viable CERSS.

1.4 ASSUMPTIONS

These are the key assumptions from which our study proceeded:

- CERSS would be structured as a new venture (whether managed by EOSAT or by another entity) and would start up by early 1991 in order to be operational in 1995.
- A "commercially viable" satellite remote sensing business is one which generates sufficient revenues, from sales of preprocessed data only, to cover capital costs and operating expenses, and provides a rate of return comparable with other investment opportunities
- Foreign entities, e.g., SPOT Image, will aggressively pursue the future satellite earth remote sensing business. CERSS will compete with these entities for the sale of preprocessed data
- CERSS would not be precluded from producing and selling value-added products and services

- CERSS must launch in 1995 to maintain data continuity with Landsat 6.

1.5 CONCLUSIONS

Our study team arrived at three overall conclusions:

- A fully commercial, independent CERSS may become viable early in the next century. By then the market may be large enough and diverse enough to support a marginally successful independent commercial enterprise. Projected market revenues will not support a fully viable commercial CERSS during the 1990s
- For CERSS to be financially viable, its revenues from preprocessed data sales must be much larger than those now achieved by EOSAT and SICORP. Increased revenues will be achievable because CERSS data will be much more "valuable" to end users (i.e. in resolution, timeliness, format, delivery, etc.)
- CERSS should be structured in the 1990s as a Government/private sector joint venture, with progressively increasing commercial investment and decreasing government involvement, until it evolves into a fully-private enterprise. (See Fig. 1-3)

We also arrived at some specific high-level conclusions:

Market-Related Conclusions

- The CERSS sensor suite must be significantly differentiated from and complementary to competitive systems. Our recommended sensor system will achieve this with a suite which has improved spatial and temporal resolutions, improved methods of data delivery, convenient data formats, and a more flexible pricing policy (see technology-related conclusions below).

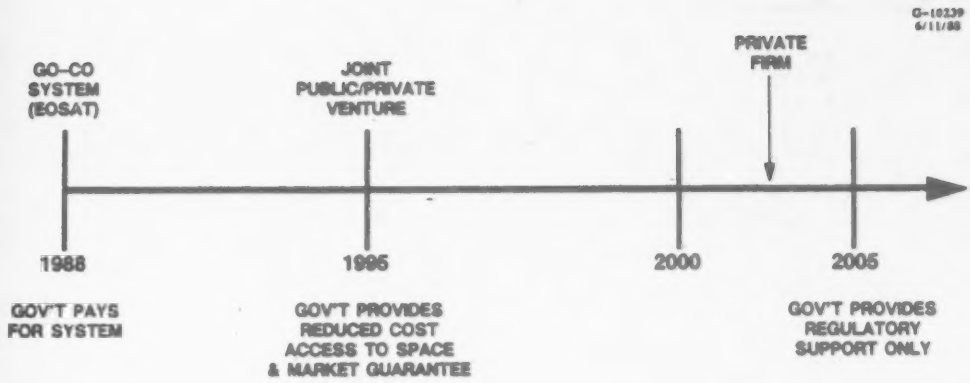

Figure 1-3 Proposed Evolution of CERSS

- Because data "value" to the end user will be much higher, and new applications will be enabled by the improved sensor suite and distribution system, CERSS revenues for preprocessed data can be significantly higher than current revenues
- CERSS will capture 50% of the domestic market for preprocessed data, because it will have commercially "valuable" data, the right market discriminators, and an inplace U.S. sales force.
- CERSS will capture at most 10% of the domestic market for value-added products and services, because this market is extremely competitive with more than 50 suppliers of value-added products and services.
- Except for revenues from foreign ground stations and royalties from their product sales, the international market will not be a primary focus for CERSS because this market is projected to be small and flat.
- The bulk of the demand for preprocessed data will be "cost/benefit" sensitive, not "price" sensitive
- Vigorous market development and education will be needed to grow existing markets and create significant new ones.

Technology-Related Conclusions

- By comparison with current systems, CERSS will require much more powerful and responsive data processing, communications and distribution capabilities. The technology for CERSS is proven and available today. Cost/performance ratios for data processing will continue to decrease rapidly. No new advances are required. There are no technological barriers to successful commercialization
- To remain competitive, CERSS must provide a sophisticated sensor suite. We have derived a baseline sensor suite which includes (a) four bands in the visible/near infrared, with 20 meter resolution and 60 km x 60km scene; (b) a single band in the visible, with 5 meter resolution and a 30 km x 30 km scene; (c) full stereo capability; (d) off-nadir viewing and (e) pointing accuracy of 0.01 degrees
- As markets become mature, more demands will be placed upon data access and distribution capabilities. The ground processing system will be configured to be more responsive within 24-48 hours
- Three technically acceptable platform options were identified: (a) a dedicated CERSS spacecraft system; (b) 'Piggyback' Option 1 - a CERSS sensor payload on a Government multimission platform; and (c) 'Piggyback' Option 2 - a Government payload on a CERSS-owned platform.
- A fourth option, 'Lightsat', is unacceptable in the CERSS role. Low payload weight, low power, small image size and poor pointing accuracy will result in high preprocessing costs and limited market options.

Pro Forma Analysis Conclusions

Table 1-3 summarizes the relative cash flows of the three selected system options. Summary figures are presented for: capital costs (single launch, including sensor, spacecraft, launcher, launch insurance and ground system); five year cumulative operating costs (exclusive of depreciation); minimum five year cumulative revenues needed for a breakeven cash flow; five year cumulative projected revenues for the years 1997 through 2001; and five year cumulative margin (figures in parentheses are losses).

TABLE 1-3
SUMMARY REVENUES, COSTS AND MARGINS FOR A CERSS
RAW DATA PROVIDER ($ MILLION)

		CAPITAL COSTS	5-TEAM CUMULATIVE OPERATING COSTS	5-YEAR CUMULATIVE REVENUES NEEDED FOR BREAKEVEN	5-YEAR CUMULATIVE PROJECTED REVENUES (YEARS 97-01)	5-YEAR CUMULATIVE MARGIN
"DEDICATED" SYSTEM		195	150	350	220	(130)
"COMMERCIAL PIGGYBACK" SYSTEM		170	150	320	220	(100)
"GOVT. PIGGYBACK" SYSTEM	INCLUDING INTEGRATION COST	125	110	235	220	(15)
	NO INTEGRATION COST	95	110	205	220	15

The best cash flow scenario corresponds to the "Government Piggyback – No Integration Cost" option. In this multimission system, the CERSS package would integrated and "piggybacked" on a Government platform at no cost to CERSS. The 5-year cumulative margin for this option is modestly positive ($15M), not taking into account financing costs. Even if reduced-rate venture financing (a 10% loan) is assumed available for the capital requirement, the resulting cash flow after financing costs is negative. But to attract commercial financing without direct Government support the venture must be profitable and return more than 30%. This would require annual CERSS data revenues of a least $60-65M, much larger than the "baseline" data revenues projected in the Market Analysis.

Financial-Related Conclusions

- A significant increase in the revenues from preprocessed data is a fundamental requirement before CERSS can be financially viable
- To reduce market risk to CERSS and enhance its attractiveness for commercial financing, the Government must guarantee substantial data purchases during the first decade of joint-venture operation. The size of the guaranteed data purchases will depend upon the selected CERSS space system configuration
- To lower the overall risk to potential investors, and thereby lower the threshold rate of return sought, the Government must guarantee CERSS loans to cover space system capital costs. The level of loan guarantee will depend upon the selected CERSS space system configuration
- The most advantageous financing approaches for CERSS are: (a) a Government-backed debt issue at a low interest rate; or (b) an interest-free Government loan.

Organizational-Related Conclusion

- A Government-Industry joint venture must be established to transition CERSS to a commercially viable business. In this partnership we would envision shared responsibilities, as depicted in Table 1-4.

TABLE 1-4

RESPONSIBILITIES UNDER JOINT PUBLIC/PRIVATE VENTURE

PUBLIC	PRIVATE
Launch	Sensors
Platform*	Ground System
Market Guarantees* or Loan Guarantee*	Operations/Maintenance

*Degree of Financial Responsibility is scenario dependent.

Policy-Related Conclusions

- Government policy must be stable, consistent and favorable over a ten-year period, to allow for development of sound organizational relationships and strong financial underpinnings, and to encourage aggressive market development
- Government-CERSS negotiations on issues such as multimission platform options, market guarantees, and Government-backed financing must be successfully completed during the first two years of this ten-year period
- The 'international consortium' organizational path can only succeed if the U.S. can recapture its place as a world leader in earth remote sensing, with a progressive and stable national program. An international consortium that protects our national interest can only be consummated from a position of strength. The decision to pursue this route awaits the successful launch of Landsat 6 and a further demonstration of national will to continue a U.S. program in space-based earth remote sensing. In any event, this path almost certainly means a delay in the CERSS launch, and therefore a gap in data continuity
- The Government, not the CERSS entity, must continue to be responsible (through NASA and NOAA) for the research and development required to maintain U.S. world leadership in land remote sensing. CERSS can only be expected to undertake research and development that is directly related to increasing its revenues or decreasing its costs.

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1.6 IMPLEMENTING ACTIONS

The implementation schedule (shown below in Fig. 1-4), which calls for a launch by late 1995, is very ambitious. It hinges on the requirement for data continuity with Landsat 6. Substantial delays in any of these required actions would impact the launch schedule and cause a gap in data continuity when Landsat 6 fails. These are the required top-level actions:

- The Government (DoC/NOAA) should begin to formulate policies as soon as possible. All policies must be in place by 1989 for final review and necessary Administration and Congressional approvals by early 1990
- New legislation and/or regulations may be required to address major implementation issues:
  - The CERSS entity should be established as a joint Government/private venture through a competitive process
  - Financing agreements must be in place
  - A guaranteed Government data purchase must be negotiated
  - If the most financially attractive option (the Government 'Piggyback' option) is to be

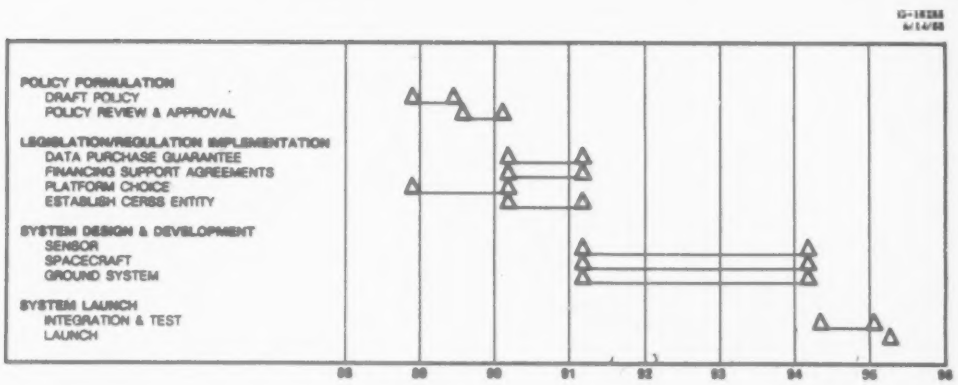

Figure 1-4 CERSS Strawman Implementation Schedule

selected, a decision must be taken by the beginning of FY 1990.

With assured timely resolution of the implementation issues, systems design and development can begin in early 1991 for completion in mid-1994. System integration and tests should begin in late 1994 for a launch in 1995. Because this implementation schedule is extremely tight (and may not be attainable if actions are not taken immediately) alternative approaches should be considered. These alternatives (which are not explored in this study) include:

- Continuing the current EOSAT-Government relationship through at least the launch of Landsat 7
- Moving forward with essential elements of the program set out above, consistent with the current EOSAT-Government relationship
- Implementing the recommended program but on a less ambitious schedule, and accepting the risk of data discontinuity after the failure of Landsat 6.

1.7 SUMMARY

Our study has concluded that with vigorous market development and education, a sophisticated sensor suite, and a timely delivery system, commercialization may be feasible. However, in the period considered for this study, CERSS is a marginal business venture with high financial risk for potential private investment. According, our study shows the creation of a viable self-sustaining commercial CERSS business will also depend critically on significant Government financial support during the first decade after Landsat 6.

We acknowledge the budgetary burden and other reasons that militate against Government involvement. But on balance the positive arguments well outweigh the negative ones, we believe, and we recommend that the Government should consider taking a proactive position:

- We recommend that the Government consider participating actively in a joint Government/private venture to bring about the creation of CERSS, with continuing but decreasing Government financial involvement (except as a likely major customer) until CERSS is fully viable as a private commercial entity

- We recommend that the Government act aggressively through NASA and NOAA to ensure that U.S. regains world leadership in earth remote sensing, and remains at the forefront of that technology
- We recommend that the Government seek additional opportunities to use earth remote sensing in the public good and promote its use as an instrument of foreign policy.

Mr. SCHEUER. Thank you very much, Dr. Brammer.

And now we will hear from Mr. Egan. Take your six or seven minutes.

STATEMENT OF JOHN J. EGAN, PRESIDENT, THE EGAN GROUP, INC.

Mr. EGAN. Thank you, Mr. Chairman.

First of all, I should explain that The Egan Group is a small consulting firm which specializes in issues to do with commercial development of space, particularly doing things such as business planning, financial and market analysis associated with commercial space ventures, and we do that exclusively.

Of the three studies represented by the other two gentlemen here and myself, ours was by far the smallest study. Theirs focused across the full range of market and technology issues and their reports, as a result, are much fatter than mine.

We focused entirely on the financial issues associated with remote sensing and I'd like to follow your suggestion, Mr. Chairman, that I deviate a lot from the prepared text and perhaps make some general comments and some comments about what I've heard earlier this morning, and then hopefully be able to respond to your questions.

In my opinion and in the opinion of our study, in the short term, we agree with both of our colleagues, that there is little prospect for the development of a viable commercial remote sensing system in the space segment and I stress in the space segment. The reason for that is quite simple. Remote sensing satellites using current technology—by that, I mean either Landsat or SPOT—range in cost in the $250 to $300 to $350 million range, depending on launch costs and various other things. They have a system life of three years, perhaps four if we're lucky, maybe five if it really gets stretched out, but that's not guaranteed. To be able to amortize that kind of investment over that short a period of time, it is impossible, in my opinion, for it to be done on a commercial basis.

That leads to two solutions. One possible solution obviously is some kind of government assistance, such as CNES provides to SPOT or such as the U.S. government has been providing to EOSAT.

Another solution which I will discuss a little bit later is to take a totally different approach to the whole thing, and I will come back to that.

I'd like to make one comment before I leave the idea of the investment. When Mr. Meier was talking earlier and you asked about the rate of return. I think it's important to realize when thinking about financing any space-related venture, whether it be remote sensing or it be something in microgravity or something else, that the investors when they look at space investments do not look at them as space investments. They look at them as one of a series of alternative investments in which they might place their money. There are obviously companies and individual investors who are very enamored with space and may feel that space is a good place to invest simply because it's the wave of the future or

exciting or sexy or whatever else. But most investors look at it simply as how does one get return on investment.

I will point out to you, Mr. Chairman, that the current rate of return on a leveraged buyout for an investment bank of New York is about 50 percent and the time is about six months. So when we're talking about 40 percent over three years by a lot of bankers' statements, it's "Why bother?" That's a problem that we have in investing in capitalization throughout this entire country because the alternatives in simply buying and selling businesses are so great in terms of just raw cash flow to the investor that that's a more serious question than we are addressing here.

But certainly when one looks at a venture such as a remote sensing satellite system with a considerable upfront capital cost, a very long-term return on investment, an unsure market, and as we've heard over and over again this morning, an unsure partner in the United States government, it doesn't look like a very good investment.

There are a couple of other things that should be pointed out. Even if all those things I just talked about were not true, you have foreign competition in the sense of SPOT, with the Japanese, and others, which are supported more actively by their government and which are taking portions of the market which might be available to the private sector.

I think that an international partnership or consortium, as has been discussed here, is probably a very good idea. At least from the taxpayers' point of view, it reduces the cost to the U.S. taxpayer of their portion by offsetting it perhaps with the cost to the French taxpayer and the cost to the Japanese taxpayer.

When you look at, as I mentioned earlier, the ways that we've traditionally done remote sensing, it's very expensive. I'm not a technical expert and I'm not sure that the problems can be solved technically for much lower cost. There are people, however, who believe they can.

It was the conclusion of our study that in order for a commercially viable space segment to be developed, that space segment would have to be a very focused space segment. By that, we mean a satellite system designed to do a specific remote sensing task. The Landsat and SPOT systems are designed to do very general tasks, whereas if you could design a sensor to, for example, be able to monitor a high- value industry—a particular crop such as grapes and things such as that which are high value-added crops, or perhaps a Mediasat type of thing for news gathering information—but these are very highly focused markets which are not served in a timely fashion. And I agree completely with Dr. Brammer that timeliness is just as important, if not more important, than the spectral bands. If you could do that, then you might be able to come up with a viable commercial system.

The only way we can see to do that is to use some type of a Lightsat technology, a dedicated small satellite, perhaps with no recording capability on board but merely take pictures and down-link and move along and avoid a lot of problems with that. We're talking a total system cost of $80 million or less. Then you have a possibility of making some effective commercial venture.

Just to sum up, the U.S. government can help in several ways. One of the ways that has been mentioned by all of my predecessors has been in using the data and in signing long- term contracts to do that which are bankable; and the other way I think they can help is if the U.S. government were to look at assisting the business development of either Lightsats and/or small expendable launch vehicles which would be able to launch these satellites at a relatively low cost.

In total summation, I think it's best to say that this is an expensive business. Unless the costs get reduced dramatically, which I do not believe they will be by continuing on a Landsat or SPOT approach, then the commercial viability of the space segment is almost zero. I believe that the value-added industry, on the other hand, is a very viable business and can prosper. It's just that space data never will.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Egan follows.]

PROSPECTS FOR U.S. COMMERCIAL REMOTE SENSING SYSTEMS

TESTIMONY TO THE U.S. HOUSE OF REPRESENTATIVES

SUBCOMMITTEE ON INTERNATIONAL SCIENTIFIC COOPERATION

SUBCOMMITTEE ON NATURAL RESOURCES,
AGRICULTURE RESEARCH, AND ENVIRONMENT

JOHN J. EGAN
PRESIDENT, THE EGAN GROUP, INC.

MAY 9, 1989

Chairman Scheuer, Chairman Hall, and other distinguished members of the House Subcommittee on International Scientific Cooperation and Subcommittee on Natural Resources, Agriculture Research, and Environment, I am pleased to have the opportunity to speak with you today on a topic of great importance to the U.S. and the commercial development of space. The Landsat program has proven the benefits of remote sensing technologies to the U.S. Government and the private sector for the past seventeen years. As the remote sensing industry proceeds from government to industry control and leadership, however, it has faced, and will continue to face, a difficult road to becoming a commercially viable industry. My comments on the commercial prospects for remote sensing are based primarily upon the results of The Egan Group's Study for an Advanced Civil Earth Remote Sensing System completed in August, 1988.

The Egan Group was asked to study the issues and prospects for private sector financing of commercial remote sensing ventures. This was one of three studies funded by the National Oceanic and Atmospheric Administration (NOAA) to evaluate options for an advanced civil earth remote sensing system to follow the recently funded LANDSAT 6 system. In contrast to the studies led by KRS Remote Sensing and The Analytic Sciences Corporation, The Egan Group's study did not include a comprehensive analysis of the overall industry. Instead, it focused solely on the prospects for private sector financing of a commercial remote sensing system. The study was conducted from February through August, 1988.

My conclusions on the commercial viability of remote sensing systems can be framed in the context of short term and long term approaches. In the short term, the high costs, short life time of the system, and limited market for remote sensing data outside the government lead to the conclusion that the space segment of civil earth remote sensing systems is not a commercially viable opportunity at this time. There is a kind of "chicken and egg" situation in the industry now where the costs are too high to develop a large market, and the market is too small and the risks too high to justify the investment necessary to develop lower cost, market driven systems. The industry needs low-cost "lightsats" designed to serve specific market niches, low-cost sensors, and low-cost transportation before a commercially viable space segment can be developed and operated. The current commercial opportunities in the industry lie in providing value added processing services and hardware and software to the industry.

This means government support of the space segment is vital in the short term (a minimum of five to ten years). However, the U.S. does not necessarily have to bear the entire burden of the next generation of remote sensing systems alone. An international cooperative agreement with the French and/or others could allow the construction and operation of an international system at a lower cost to the U.S. taxpayer. There are risks associated with such an action, however, so it should be considered very carefully before a commitment is made.

In contrast to the short term situation, I am optimistic that in the long term commercially viable remote sensing space segment can be developed and operated by U.S. companies. A great number of changes to the current situation must occur between now and then, however, to make such a commercial system a reality. As mentioned

above, the overall costs associated with remote sensing systems must be drastically reduced. It will be much easier to build a viable business around a "lightsat" based system where the total system costs are below $40 million, than it is now when total costs top $200 million.

Lower cost systems will also allow companies to develop strict market driven approaches to meeting the needs of its customers. Private sector systems in the future will be designed to be commercially viable, rather than as technical showpieces, as has been the case with the Landsat satellites. For example, I can easily envision the development of a network of four or more low-cost lightsats designed to meet the needs of specific agriculture users. The network as a whole would provide services on a timely basis to a narrowly defined, viable market niche. It would be designed to be cost effective and commercially viable. It would not be a "state-of-the-art" system. Other systems serving niches such as the media, environment, and oil industry are also possible.

The Government has a large role to play in fostering the eventual development of a commercially viable remote sensing industry. It is a long term issue, and the short term problems and plans are likely to take precedence over the next few years, but I urge the Congress to keep the long term objective of facilitating the eventual development of a commercially viable remote sensing industry in mind.

The remainder of my testimony covers the results of our study and discusses the basic issues associated with private financing of commercial remote sensing systems.

ENABLING TECHNOLOGIES

A premise of our effort was that if the costs of remote sensing services can be drastically reduced and, in some cases, the timeliness of data delivery improved, the market for the services has the potential to undergo significant growth. Development activities currently underway in two key areas have the potential to significantly reduce the costs for these components and thereby the overall costs of a remote sensing system.

- Recent development activities on the use of lightsats have shown that these small, relatively inexpensive satellites may be capable of supporting remote sensing systems. Many industry professionals warn that their capabilities have been oversold. If lightsats do prove viable, however, they could not only reduce system costs, but may also allow ventures to provide timely data collection by launching multiple satellites.

- A number of low-cost, small commercial launch vehicles are currently under development which may greatly reduce the cost of transporting a satellite into orbit.

RISKS FACING A COMMERCIAL REMOTE SENSING VENTURE

The high risks associated with the remote sensing industry will impact on the ability of a commercial remote sensing venture to obtain financing. A summary of the risks is presented in the four areas below.

- Technical Risks - Technical risks associated with the spacecraft, launch, sensors, and operation of a system are understood and generally perceived to be manageable. Primary areas of uncertainty lie in the ability of the new generation of low cost launch vehicles and lightsats to support the industry's needs.

- Market Risks - The market for remote sensing services cannot currently support a commercial remote sensing venture. For most applications an extensive (and expensive) market development program is needed before a commercial venture could operate profitably.

- Competition Risks - Most of the competition a commercial venture would face would be from government operated or supported systems (e.g. SPOT, ERS-1). An approach which may help counteract this would be for a commercial venture to address a market niche not adequately addressed by current or planned government systems.

- Regulatory Risks - These include the potential for sudden, drastic changes in government policy which could have a significant effect on a commercial venture's prospects.

FINANCING ENVIRONMENT

The ability of a company to raise financing for a remote sensing system will depend on the economic soundness of the system and the underlying requirements of the equity and debt markets. It will be much less dependent upon the financing mechanism (e.g. limited partnership) it has selected. How the attributes of the debt and equity markets relate to the financing prospects for commercial remote sensing ventures is discussed below.

Equity investors, as risk takers, are more likely than providers of debt financing to invest in remote sensing ventures. However, equity investors are still extremely selective and will require the following:

- A demonstrated market for the system's services. This will most likely be in the form of pre-launch commitments to procure a system's data

- A demonstrated ability to control costs and schedules. Investors will want to see cost commitments from the suppliers of major components.

- A potential annual return on investment in excess of 50%. Investors can

realize similar returns on lower risk investments and would require returns at least this high for remote sensing ventures.

Knowledgeable equity investors can play an added role by "legitimatizing" the venture in the eyes of the financial community. In fact, until outside investors see industry participants investing in the space segment of the industry, it is unlikely they will invest a significant amount in the industry.

Debt providers are not, by nature, risk takers. Therefore, they will require more severe actions to manage risks than would equity investors. These actions include the presence of:

- o Demonstrated pre-launch commitments to purchase services which would cover close to 90% of the total system's costs
- o Adequate steps to avoid a performance risk
- o Demonstrated ability to control costs. Cost commitments will be required from suppliers of major system components.

FINANCING CONCLUSIONS

The overall financing and risk characteristics facing the remote sensing industry lead to the following conclusions on the prospects for financing a commercial remote sensing system over the coming five to ten years.

- o The current non-discriminatory data access policies may be restricting investment in systems which would benefit from some level of discriminatory access to the data. This is an issue which requires further analysis.
- o The three types of actions industry could take to improve its prospects for obtaining financing are:
  - Demonstrate its ability to manage costs and schedules
  - Demonstrate the existence of a market for the service
  - Develop an effective strategy for entering the market.
- o The current state of the market and other high risks in the industry are such, however, is such that some level of government commitment or support is required for a venture to obtain financing.

GOVERNMENT ACTION PLAN

The recommendations discussed here are those included in our study and are designed to improve the overall long term environment for commercial remote sensing

ventures, in lieu of providing direct subsidies as has been the case with the LANDSAT commercialization effort. If implemented, they will not guarantee the development of a commercially viable remote sensing industry, but will greatly improve the prospects of that occurring.

These steps are designed to support the long term development of a commercially viable remote sensing industry. They should be taken in conjunction with short term steps to assure the continuation of a U.S. presence in the space system market either through Landsat 7 and beyond or through U.S. participation in an international consortium.

Phase 1 - The government will determine its own requirements for operational remote sensing data.

Phase 2 - The government will make a decision as to how best to meet its needs. Its four options are:

- Build and operate a system itself
- Provide a direct subsidy to a private sector company to develop and operate a system. This is the approach taken with the LANDSAT commercialization.
- Purchase data from a system supported by another nation's government (e.g. SPOT)
- Take steps to promote private sector investment in commercial remote sensing systems designed to meet the needs of the government and commercial markets.

If the final option is chosen, the government can proceed with Phase 3.

Phase 3 - This entails government action in four areas designed to improve the overall environment for commercial remote sensing ventures. These are:

- Market Assistance - The government should serve as a consistent, dependable customer for commercial remote sensing systems over a multi-year period. This is the single most important step it could take in improving the prospects for private sector financing of commercial remote sensing systems. It should also fund the development and offering of a series of courses designed to improve industry's general understanding of how remote sensing could help address business needs.
- Reduce Regulatory Barriers and Risks - The government should take actions to eliminate support to the LANDSAT program, clarify potentially restrictive policies (e.g criteria under which the Secretary of Commerce could withdraw a license), and continue efforts to promote a strong commercial launch

industry. The government should also study all aspects of the non-discriminatory data access issue including whether relaxing certain provisions may spur investment.

- Provide Limited Direct Government Support - The government should provide limited, non-monetary support to commercial ventures including low cost or free launches and access to government ground stations and test facilities.

- Support Technology Development and Demonstration - The government should maintain a strong, on-going role in applied research for remote sensing technologies. It should also enter into a joint venture agreement with one or more companies to develop and operate a lightsat prototype to determine if low-cost lightsats can support remote sensing systems.

If the government is truly interested in promoting the development of a U.S. commercial remote sensing industry, it should implement the recommendations contained in this report. These actions will not guarantee the creation of a viable industry. If they are successful, however, they will lead to an industry, financed and operated by the private sector, which does not require government subsidies and contributes to U.S. leadership in the commercial development of space.

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Thank you for the opportunity to present my thoughts and suggestions to this session. I urge you to carefully consider the long term effects of decisions made on the future of Landsat and allow the opportunity in the long term for the government to support the development of a commercially viable, market driven system or systems.

Mr. SCHEUER. Thank you very much, Mr. Egan.

Could you elaborate on what you mean by a contract that is bankable?

Mr. EGAN. A contract that is bankable is a contract between two parties—and one of them may or may not be a government—in this case it would be the government, which a very conservative financial institution would view as virtually ironclad. All contracts that the government signs—or most contracts that the government signs, all that I'm aware of, have a clause in them that say they can be terminated for the convenience of the government or if funding is not made available.

So if I'm going to get into a business where I'm going to invest $80, $90 or $100 million, or if you're talking about building a land remote sensing satellite system, $300 or $400 million, and the government is the largest single market for my data, and I can't get the government to sign a long-term contract that they will take that data from me, then my financial exposure is tremendous and no banker will finance it. You simply cannot walk into Wall Street or any other bank and--

Mr. SCHEUER. In other words, your financial exposure is tremendous because no banker will extend credit on that kind of a contract?

Mr. EGAN. Right. If the contract is not sufficiently binding on both parties that the bankers do not feel that the company will derive revenue from that contract on an assured basis, then they won't lend money. And equity sources of capital are looking for high return. Government contracts are not noted for their high return. And debt suppliers are looking for assurances that they will be repaid.

Mr. SCHEUER. Equity holders are looking for some kind of a leveraged return, leveraged on debt.

Mr. EGAN. That's right.

Mr. SCHEUER. And what you're saying is, that if funding isn't assured on a continuous systematic basis over a long term, you can't get the debt. And then, because you can't get the debt, you can't provide the minimum leveraged return that the financial market is going to demand.

Mr. EGAN. It is very difficult to get adequate equity, given—in addition to what you've said—also the fairly large sums of money we're looking at, large sums of money that have historically been able to be raised in the private sector. The problem with the space segment—the example is the Alaska pipeline. That was all privately financed and it did not involve any government guarantees, but we all knew that there was a market for crude oil and once it was made available it would be able to be sold.

The problem you have with remote sensing and a lot of other space-related activities is there's no market of certainty. And while the government makes up a large portion of that market, if that portion that is known, which is the government market, is not sure, then the risk to the investor is increased. That's what causes the problem. You can raise capital. You can raise billions of dollars in capital as long as the risks are understood and contracts can be drawn which will provide investors, particularly debt providers, with enough guarantee that they will receive a return on their in-

vestment. That's not the case in the remote sensing area in my opinion.

Mr. SCHEUER. Well, thank you very much, Mr. Egan.

Let me ask the panel, is having a 5-meter resolution capability a key to commercial success? Maybe I can clarify by asking, won't a five-meter data be much more expensive than data with courser resolution and did your studies look at the cost of the five-meter data and the impact of these costs on the demand? In other words, if you want to provide five-meter data, it's going to increase costs and for the private sector involvement and the financing to be viable there has to be a demand to provide a return on the increased cost of providing the five-meter resolution.

Is there a demand for the five-meter resolution? And if there isn't, should we say that that five-meter resolution ought to be provided by NASA or some other source, but should we therefore conclude that if you're looking to a strictly commercial venture we shouldn't ask them to provide five-meter data resolution because the demand won't justify the increased costs? In other words, will the demand justify the increased costs for five-meter resolution?

Mr. MEIER. In our market studies we found specific examples of other industries that could utilize three to five-meter resolution. Examples of that are the engineering and construction industry, mapping, the insurance industry, the legal industry, the media, real estate, simulation, DOD, Department of Interior, etc.

Specifically, our recommendation is to provide, first of all, a stereo capability which is fore and aft rather than side to side. This increases the timeliness of delivery of the data.

Secondly, by having a single spectral channel with five- meter resolution, that enables you to sharpen all of the other spectral bands and get a little bit of extra information for mensuration.

Mr. SCHEUER. Well, the question is, will the private sector buy it? Is it commercially feasible? There's no point in producing the data unless there's a market for it that contemplates the increased cost of providing that data.

Mr. MEIER. Today, that market is satisfied by aerial photography and it is less expensive to satisfy that market using satellite data than it is to satisfy that market using aerial photography.

Mr. SCHEUER. Well, does that mean that we're going to have to look to the long term, well into the next century, before the private market will support the cost of satellite remote sensing data as opposed to aerial photography?

Mr. MEIER. Remembering in the conclusions that we came up with that the government has the largest market requirement for data, what we found is that if we satisfied the federal government's requirement for high resolution data and cartographic type information we would also satisfy private industry's demand for that same type data.

Mr. SCHEUER. Would any of the other members of the panel care to answer this question of whether the market will provide support and an economic rationale for the increased cost of providing five-meter resolution?

Dr. BRAMMER. Our feeling is that, yes, it would, that a five-meter sensor in time, if it could be put on a platform with a multi-spectral sensor, that a black and white portable five-meter sensor

would in time help to create markets that do not currently exist. There are some markets for which cost is not really the issue, but if you don't have the resolution they can't use the data.

Mr. SCHEUER. If they do have the resolution, can they not only use the data but pay for it? That's my question.

Dr. BRAMMER. We believe that in time those markets could be created and a five-meter sensor could be made to pay for itself, yes, sir.

Mr. SCHEUER. Mr. Egan?

Mr. EGAN. I think I'm not in a position to comment on the technical side, but it's a chicken and egg problem in the sense that since a five-meter resolution does not exist, then people who are in the market are not preparing to use it. It's like asking someone, "What are you willing to pay for something that you've never seen?" That's a very hard question for people to answer.

The solution, it would seem to me, would be, if the government has the need for five-meter resolution, if the government can come to that consensus that they have the need for five-meter resolution, then the government should go ahead on its own need and try to procure that on a commercial basis. Once it's available, then if there is other additional commercial need, it will develop and the market will expand.

But to say should we have five-meter or should we have something else is a very hard question to answer and makes the investment very difficult to determine.

Mr. SCHEUER. The principal government purchaser of all of this data is the Department of Defense. As you all know, they have their own capability of producing a resolution far better than five meters. So they are not your market. Is there any identifiable market among other government agencies and in the commercial market that would justify the cost of going to five-meter data?

Mr. MEIER. Mr. Chairman, I would like to answer the initial question you asked with an affirmative and repeat that the markets that can use this information are the cartographic markets, engineering and construction, mapping, the insurance market, the legal market, the news media, real estate, simulation, DOD and the Department of the Interior.

Mr. SCHEUER. How about EPA?

Mr. MEIER. Yes. Any industry that relies upon putting other information into a cartographic type form, which is one of the major uses of satellite data from Landsat and SPOT, can use this type of information.

Mr. SCHEUER. How about the Department of Energy?

Mr. MEIER. In some specific cases, yes.

Mr. SCHEUER. Well, we are only interested in the some specific cases in which they can use it. The whole thing is predicated on the specific cases in which these users can make profitable use of the data and are in a position to pay for it.

Does anybody else want to answer that?

Dr. BRAMMER. One more example that I think is relevant here, the utilities have continuing need for mapping and remapping their land to check on the status of power lines, rights-of-way and so forth. Currently they are satisfying their needs with aerial pho-

tography services. The resolution of the current sensors, while applicable for part of their problem, don't solve the whole problem.

The higher resolution sensor on the order of three to five meters would be a big step forward to meeting this one particular case, and I believe this is a significant market.

But let me stress also that it's not purely a question of five meters. It's a question of distribution and it's a question of pointability. It's a question of getting the data into the form that the customer can use. It's fairly easy to latch onto technical questions about five meters or this band and so forth, but it's a much more complicated problem than that dealing with ground processing and timeliness and so forth.

Another application is in the news media. We have done some limited land remote sensing image processing for the news media and, of course, timeliness is critical there. The aspect of the sensor that would be important, in addition to the resolution, is the fact that you have some degree over how you point it so that you could cover areas of interest to them without necessarily relying on the satellite being in the orbit that you need at the exact time of the news event. So it's more than just a question of resolution. It's a question of a lot of other variables that are just as important.

Mr. SCHEUER. You may have heard Mr. Julyan of SPOT testify earlier this morning that royalties from data sales could cover the cost of SPOT's space segment by about the turn of the century.

Do your studies support that claim?

Mr. MEIER. The KRS study does support that claim. Specifically, in our high-share market, what we have found is that at the turn of the century or slightly beyond, the revenues are approximately equal to the space segment cost.

Mr. EGAN. I think that an issue needs to be raised in this. I don't disagree that possibility exists for covering the cost by that time if the markets expand.

In kind of going back to your last question, Mr. Chairman, and bringing the two of them together, I think one of the key issues here is, it is true that markets exist for all of the areas that were outlined by my associate here in all of these things. But these various markets are solving their problems some other way now. So the point is, it is not a matter of simply providing a capability to do remote sensing by satellite and hoping that people will beat a path to your doorstep. Much of what needs to be done in the future is consumer education because people are now using other systems. For example, the insurance industry is now solving its problems which might be solved by remote sensing another way. So is the power industry.

So if we're going to make these markets into viable revenue generators, a lot of consumer education has to happen.

Mr. SCHEUER. Consumer education?

Mr. EGAN. Customer education, if you will.

Mr. SCHEUER. You're talking about educating the major corporate and governmental potential consumers?

Mr. EGAN. Exactly.

Mr. SCHEUER. You're not talking about 242 million Americans.

Mr. EGAN. Not exactly, but to some degree. The reason that people—the example that often comes to mind and is used is in a

forum probably much like this in the early 1950s is the computer. The vice president of IBM was asked what the entire world market for computers was and he answered, "Eight," and he considered himself to be absolutely accurate. The computer was twice the size of this table and could add, subtract, multiply and divide quickly and that was about it.

We have now lived for 30 years with computers and we collectively, the consumer, have learned what they can do for us. So there's a lot of pressure on the market for the more things that computers can do. Right now very few people in this country, either the general public or the buying public in the sense of corporations, know what remote sensing can do for them. So, as a result, they don't ask for it. They are solving their problem in another way. And unless remote sensing solves it in a cheaper way than the way they are doing it now, they won't use it.

Mr. SCHEUER. I'm not sure the consuming public, if you applied that phrase to include potential government users—I'm not sure the consuming public, as Mr. Meier has described it, from that laundry list of government agencies you ticked off, I don't know if they are aware of the potential of remote sensing to their mission.

You mentioned a half a dozen different government agencies. It seems to me they could take advantage of consumer education and could be made aware in a way that they are not aware now of the usefulness of remote sensing to them in fulfilling their mission.

Would you disagree with that?

Mr. MEIER. No. I'd like to agree with that and specifically what we found in our study was that new products have to be developed which are "products". You don't take raw data and give it to a user. You need to have a commercial product that many users understand and can use to better their decision-making process.

Mr. SCHEUER. These products have to be user-friendly, in other words?

Mr. MEIER. Yes. And also I might add that the cost of developing those products was not included in our study and may range from a million dollars per product to ten million or to some unknown quantity.

Mr. SCHEUER. Can I ask all of you, what in your respective views, are the key lessons to be learned from our experience with Landsat commercialization up to now? What does Congress and what do the executive branch decision makers have to learn from the experience we've lived through in the last five to ten years?

Dr. BRAMMER. I think one of the more obvious lessons from this is the difference between a steady commitment and the value—if you look at the success of the SPOT program, for example, from a commercial point of view I can count of SPOT as a supplier. I can plan on that. I know what their capabilities are. Mr. Julyan and I have had many conversations about SPOT's products and services and while there are times I wish they would do better, they have improved a lot over the years and we enjoy working with them. I can count on them as a reliable supplier.

So that's a valuable thing for planning in the future. I think it's obvious in our own program that that has not been the case. So I think that's probably a lesson to be learned.

Mr. SCHEUER. We've had a lot of testimony on that this morning.

Are there any other lessons we can learn?

Dr. BRAMMER. I think another lesson is that this field is not going to be developed by trying to be the low cost or the low cost solution. I think we are going to continue to need to develop technology. Again, the advantage of the SPOT system for stereo coverage and rapid revisit are very important to us in some of our applications and if we try to rely on technology that—while it may come down in price over the next few years—does not contain advanced features, I think we're going to miss the boat.

Mr. SCHEUER. How do we finance the considerable R&D expense of producing in effect pure science in terms of improved technology where you haven't yet defined an application of product or a market? Who is going to pick up the tab for that? Who should pick up the tab for pure science in elaboration of further high technology advances in this remote satellite imaging technology?

Mr. EGAN. If I may, I will first I think disagree with Dr. Brammer in saying that the future is not in the hands of coming up with new sensors. To answer your question, Mr. Chairman, it has not historically been the role of industry to lead in the development of new science. The Polar Platforms, both of them—the European and the U.S. one associated with the space station—are pure science programs.

We are here to talk about commercial, at least to some degree. And commercial business makes its money by using reliable, proven technology to do what it sets out to do to produce and develop a product for the customer.

If I had to go back and say what lesson have we learned from the entire Landsat program, it is that Landsat has been a technological leader without a market. We have developed data. We have developed technical capabilities. And then we've turned around and said, "Golly, gee, look what we can do. Let's go see if we can find somebody to sell this to." That's the wrong way to approach a market.

The way to approach the market is to say what does the customer need and how might the space technology be used to satisfy that need, and then go develop the technology which will satisfy that need as simply and as cheaply as possible.

As long remote sensing remains the major issue of science, technology and advanced development, it will never have commercial application or will never be commercially viable. Business won't pay for $10 $15 and $30 million sensors. They won't.

Mr. SCHEUER. Well, maybe there's a role for government to support pure science here in developing state-of-the-art that we can't visualize now, a whole new state of the art for thousands of years pure science investigations have been going on since Galileo dropped an apple from the Leaning Tower of Pisa—who was that—

Mr. EGAN. I think the apple was Newton, Mr. Chairman.

Mr. SCHEUER. Okay, it was Newton. And Galileo, what did he do? He dropped the weights off the tower and he not only didn't have government support but he enjoyed considerable opprobrium from the church community at that time.

Now the march of science doesn't stop or it shouldn't stop. We understand from all of the testimony this morning what we have to

do to make investments in remote sensing attractive to the private community.

How do we make policy to encourage pure science in remote sensing where we may not know in advance what the uses are and what the market is and who the ultimate user may be? We're certainly not going to stop the march of investigating space from the point of view of pure science. What's going to be the formula there? Should we assign, for example, the R&D function to NASA and let NASA pioneer new R&D and then let these consortia or let a consortium do the applied science?

Dr. BRAMMER. I think NASA would be a reasonable place for this research, particularly in view of the growing interest in global change. There ought to be a considerable investment I think in terms of new science and technology for remote sensing and NASA would seem to be a logical organization to lead that research.

Mr. SCHEUER. On the assumption that Landsat should be market-driven and not high technology or pure research-driven.

Dr. BRAMMER. I think there will be in time some commercial spinoffs from that technology, but if you look at the plans for the Earth observing system and the space station and so forth, there are new sensors proposed there that, while the initial research and technology development could be done then, in time they would lead to some of these higher technology sensors which at some point might be commercially viable.

Mr. SCHEUER. The last question. We've talked a lot about consortia or a consortium involving perhaps up to four partners, the Russians, the French, the Japanese and the Americans. Will the future market for remote sensing data provide sufficient market share for at least these four groups that we have mentioned who will be competing presumably in the distribution and sale to the commercial market of the data they may jointly produce together? Is the market going to be sufficient to meet the costs of a three or four member consortia?

Mr. MEIER. I'd like to comment on that. First of all, when you form a consortium you'd like to provide data which, rather than competing with your partners in the consortium, allows cooperation with your partners in the consortium.

The other comment I'd like to make is that when you form the consortium you are reducing the financial investment that you as a single partner in that consortium need to make.

Mr. SCHEUER. As compared to the investment you would have to make if you, as a nation, were going it alone?

Mr. MEIER. Correct.

Mr. SCHEUER. In other words, aren't there some obvious costs deficiencies of scale that where the whole in terms of cost effectiveness, cost efficiency is greater than the sum of the parts, where you can do the total job through a consortium at a cheaper cost than would be incurred if four individual national groups were competing with each other to produce the same volume and quality of data?

Mr. MEIER. Yes. Specifically, the money that you do not have to invest if you were to do the job yourself can be used for other purposes such as research activities.

Mr. SCHEUER. Yes.

Dr. BRAMMER. I think the financial appeal of a consortium is obvious, although I would like to point out that many of these markets—and your question deals with is the market big enough—many of these markets are yet to be created and the terms and conditions under which such an international consortium would make data available to the private sector which could then go out and develop these markets would be a major issue. Somehow the management systems for the consortium and the terms and conditions under making the data available and lack of restrictions on which areas get covered and who decides who gets priority on scheduling the satellite—all of those would be important questions to know whether the consortium management system could really help the private sector grow the business.

Mr. EGAN. I think if you look at the examples, particularly INTELSAT and INMARSAT which are good examples of international space cooperation, they have succeeded to a large extent in overcoming the problems that have been for their own systems. They will set a focus. As INTELSAT is finding out with the advent of regional satellite development, once they set a focus, other interested parties may change that focus and develop their own capabilities.

So what I think an international consortium would do clearly, as has been stated, the financial advantages are great, but because of the nature of the technology and the nature of satellite systems, they will also at that point set in concrete the direction in which remote sensing is headed. That's a positive thing assuming that direction is well thought out and well founded.

It is also a positive thing in that if things are left out, if niche markets are not being served by this internationally focused direction, then there may be the opportunity for small private sector activities using new technologies or different lower cost ways of solving the problem to also get in the business in addition to the international consortia.

Mr. SCHEUER. Gentlemen, this has been an extremely productive and helpful panel and we are grateful to you for your patience. It's now 20 minutes after one and you've all been waiting here several hours to take center stage. We appreciate your testimony very, very much.

The hearing is adjourned.

[Whereupon, at 1:20 p.m., the hearing was adjourned.]

APPENDIX

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515
(202) 225-6371

May 4, 1989

Hon. Dan Quayle
Vice President
White House
Washington, D.C.

Dear Vice President Quayle:

The National Space Council will meet next week to discuss the future of the Landsat remote-sensing satellite system. As you are aware, the Science, Space, and Technology Committee has strongly supported the development of the Landsat system, from its early days as a NASA program through its commercialization under the Land Remote-Sensing Commercialization Act of 1984.

The National Space Council's review comes at a critical time in Landsat's history. Funding for Landsats 4 and 5, which was threatened before your intervention in March, runs out in early July. Landsat 6, not scheduled for launch before mid-1991, offers only a single satellite with slight technological improvements over the existing system. With Landsat's history of budget cuts, threatened program shut-downs, and system downscoping, users and potential users of Landsat all over the world have called into question the United States' commitment to its civilian remote-sensing program. Our international competitors -- particularly the French and the Soviets -- have aggressively capitalized on our indecision.

We urge the Council to reaffirm strongly this nation's commitment to a technologically-advanced, internationally-competitive civil remote-sensing satellite system.

Landsat's importance is clear. Maintaining the Landsat program is critical to the national security as a unique source of military and economic intelligence. At a time when the world has become aware of the fragility of its natural resources and the threat of environmental disasters, Landsat has become a critical tool for environmental knowledge and management around the world. And the commercial market for Landsat data -- from finding oil and gas to planning new school districts -- has been growing dramatically.

But we can no longer afford the annual ritual of agony over the Landsat program. We need a long-term, stable policy for the rational

development of the Landsat system. We urge the Council to include the following elements in a long-term Landsat policy:

1. Beyond Landsat 6, the government should commit to developing and launching a system to take us at least to the year 2000.

2. Industry should continue to play a critical partnership role with the government, both to reduce the government's costs and to bring the private sector's expertise in marketing to bear.

3. Estimates of the potential commercial market should be realistic, not driven by ideology. Efforts to commercialize the Landsat system should be paced by the development of sufficient commercial markets. Commercialization can be successful only with a long-term, predictable government policy and sufficient government support.

4. The technology of future Landsats should be sufficiently advanced to be internationally competitive.

5. International financing arrangements should be pursued only when the U.S. is committed to a stable, long-term program. We should negotiate with potential international partners from a position of strength, not weakness.

6. Funding for Landsat 4 and 5 operations should be secured to ensure continuous data coverage and to reassure users of the U.S.'s commitment to the Landsat program.

We commend you for your continued leadership on this critical space policy issue, and look forward to working with you and the other Members of the National Space Council in putting the Landsat program back on the right track.

Sincerely,

Bob Walker

ROBERT S. WALKER
Ranking Republican Member

Robert A. Roe

ROBERT A. ROE
Chairman

THE WHITE HOUSE

Office of the Press Secretary
(London, England)

For Immediate Release June 1, 1989

STATEMENT BY THE PRESS SECRETARY

The President today announced he had approved funding for continued operations of Landsat satellites 4 and 5 and for the completion and launch of Landsat 6. The President's action endorsed a recommendation from the National Space Council chaired by Vice President Dan Quayle. The President also directed the National Space Council and the Office of Management and Budget to review options with the intention of continuing Landsat-type data collections after Landsat 6.

Landsat, which takes detailed photographs of the earth, is the U.S. Government's civil, space-based, land remote sensing program. Landsat-type imagery data is important for such applications as global change research, environmental monitoring, law enforcement, natural resource estimates, national security and a variety of private sector uses. In addition, Landsat provides a visible symbol of the U.S. commitment to, and leadership in, the use of space for the common good.

Over recent years, it has become increasingly evident that commercializing the entire Landsat program would not be feasible until at least the end of the century. Since earlier government planning was based on commercializing the entire program, the absence of near-term commercial viability threatened continuity of Landsat and jeopardized continuity of Landsat data. The National Space Council, at its first meeting on May 12, recommended the action endorsed by President Bush today.

Continued operation of Landsats 4 and 5 will require an additional $5 million in FY89 and $19 million in FY90. Cost of completion and launch of Landsat 6 by 1991 has already been included in the Commerce Department budget.

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